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PREFACE

We are sending out to the world the Fourth Volume of our Studies. It is encouraging to find that our Departments are becoming increasingly active in research work. In fact, for the present volume we have had more papers than we could print; and we have been forced to hold over a few for the next volume. The Vice-Chancellor thanks his colleagues in the University for this generous response towards an undertaking which he hopes will bring credit to the University.

March 31, 1928 G. J.

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THE GOLGI APPARATUS AND VACUOME THEORY

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INTRODUCTION.

The object of this paper is to awaken an interest in the works of Parat and his collaborators on the Golgi apparatus among the English-speaking cytologists and such others who either owing to paucity of literature or ignorance of continental languages are precluded from following the discussion that has been going on for the last 3 years as regards the homology of the Golgi apparatus and Vacuome. The necessity of explaining Parat's views becomes imperative because of the fact that even now many of the contributions on the subject in English show complete ignorance of the existence of a series of interesting papers written by Guilliermond, Parat and his collaborators. The Vacuome theory as propounded by Parat has been the subject of a great deal of discussion at the last two "Reunion (Turin and Liege) of Association des Anatomistes." Adherents to Parat's view about the nature

and function of Golgi apparatus are increasing in numbers and it is high time that we put to the test the ideas held by the French School as regards the structure of this cell organ, and expose them if they are found to be a fraud. If, on the other hand, they are found to be nearer the truth, it is but fair to give them a proper place in scientific literature.

This paper was originally written in the department of Anatomy and Histology, Sorbonne, Paris, in 1925. Through pressure of work and various other causes, its publication has been unusually delayed. I have pleasure in expressing here my indebtedness to Dr. Parat for criticisms and for placing his personal library at my disposal and to Professor J. Brontë Gatenby for going through the manuscript of this paper.

HISTORICAL ACCOUNT.

It is now a well-known fact that in 1898, the great Italian neurologist Camillo Golgi (41) discovered and described for the first time the "apparato reticolaro interno" in the neurones of the central nervous system by the silver nitrate methods. Holmgren (46) and Nelis (64, A.) and others in 1899, put in evidence a system of clear canalicules in a large number of cells. Their marked resemblance of form and position with the Golgi apparatus led Cajal to call them canalicules of Golgi-Holmgren. Golgi himself seems to have given it a name provisionally, but his pupils and admirers took it literally and gave it the bewildering and misleading name of apparatus of Golgi. Veratti (1899, 92) obtained results similar to those of Golgi by silver nitrate methods. Ballowitz (2) in 1900, described the "Centrophormies" in the posterior epithelium of cornea and compared them with the apparatus of Golgi. A little later Kopsch (1902, 49) obtained very interesting results by the osmium technique invented by him. His work was considered to be of such importance that Weigl (93) and others called this newly discovered cell organ Golgi-Kopschen Apparat. Von Bergen (6) in 1904 obtained

results confirmatory to those of Kopsch by the osmium technique. The Golgi apparatus was subsequently described by Pensa (1901—1914, 81, 82, 83) in supra-renal bodies, cartilage cells, and plants. Negri (1899, 64) described them in gland cells, Stropeni (1908, 89) in liver cells, Perroncito (1910, 84) in sex cells, Marcora (1911, 55) in degenerating nerve cells, Sangiorgi (1909, 86) in kidney, Barinetti (1912, 3) in its (Golgi apparatus) position relative to centrosome, D'Agata (1910, 24) in stomach epithelium, Biondi (1911, 9) in choroid plexus, Corti (1913, 19) in the intestinal epithelial cells.

Prenant (1888) was the first to describe the osmic acid method as suitable for the detection of bodies akin to the Golgi apparatus. By prolonged action of osmic acid (2%) on the cells of Gastropods (Helix and Arion) he demonstrated that "platten" called "nebenkern" were visible. The credit, however, must go to Kopsch (49) who in 1902 definitely stated that the osmic (2%) method was suitable for the detection of Golgi bodies. Von Bergen (6) in 1904, used osmium material to show systems of filaments in a network described by the Italian School. Later, in 1906, Sjöval (88) described the Golgi apparatus (osmium method) in the somatic cells and eggs of mammals. Ramón γ Cajal (16—18) with his pupil Fananas (1904—1915, 31) studied the Golgi apparatus in embryonic cells. Pensa (1913, 82) showed the development of the Golgi apparatus in the course of ossification, followed by Cajal (1915, 18) and Deineka (1916, 28).

Thus we see that even so far back as 1912, a number of workers had carried on cytological investigations on a variety of tissues in the animal body. They laboured however under great difficulties, for cytological technique as it is known at the present day was unknown then and naturally rather crude methods were employed to detect the various cell organs. Modern Cytology may be said to have grown within the last 15 years. During this period a series of interesting papers by Gatenby, Hirschler Duesberg, Cajal, Pappenheimer,

Cowdry, Ludford, V. Nath, Brambell, Da Fano, King, Tello, Berenberg-Gossler, Morelle, Kopsch, Kolatchev, Bowen, Saguchi, Nassonow, Parat and others have been contributed to elucidate the nature and formation of the apparatus of Golgi in somatic and germ cells.

THE GOLGI APPARATUS AND VACUOME.

According to the views held by the majority of Cytologists, the Golgi apparatus exists in cells in the form of filaments or a close network in the early stages and generally juxta-nuclear in position. The network later breaks up and gives rise to varied forms of Golgi bodies. Regarding its chemical composition very little is definitely known. It is generally believed that at least a part of the apparatus is lipoid in nature. Gatenby thinks that the constitution of the apparatus is rather analogous to that of mitochondria, *i.e.*, proteid combined with phospholipoids. Bowen thinks that they are made up of two things, the one colouring lightly and the other strongly. Cowdry is of opinion that the space occupied by the Golgi apparatus is of a liquid nature. Parat and Bergeot (74), however, claim that in the epithelial cells of the intestine and the stomach of Amphibians, the Golgi apparatus cannot be considered to be of the nature of lipoids. Again, the Golgi apparatus is generally supposed to be a structure of varying form, in many cases crescent-shaped or ring-like, containing a specialised area of cytoplasm in its interior which goes by the names of "archoplasm," "sphere substance," "idiosome," etc.

During the last three years, Parat (66—80) with his collaborators has shown that the Golgi apparatus which he calls Vacuome, as revealed by "coloration vitale," in its natural condition is always spherical in form. Parat believes that the varied forms of the apparatus so far described are artefacts caused by the action of strong fixatives. He goes further to add that the close network of the apparatus in its

early stages results from the running together of Golgi bodies and mitochondria under the influence of certain fixatives. Parat and his collaborators have used both the classical fixatives and vital examination methods side by side and have come to the conclusion that the Golgi bodies and Vacuome are one and the same structures. In coming to this conclusion the methods found most useful were Kolatchev-Nassonow osmium modification and Parat's neutral red solution.

Regarding its constitution Parat believes that the contents of the Vacuome are of the nature of solutions of crystalloids, in many cases with a little colloid, the liquid being acidic in reaction. This is, in essence, Parat's Vacuome theory, which differs markedly from the views held by most of the leading Cytologists on the nature and constitution of the Golgi apparatus.

The Vacuome theory dates back from the time when Dangeard (1916, 25) described it in vegetable cells for the first time. Later Guilliermond (1920, 42) and Mangenot (1922, 44) gave a proper interpretation to the vague ideas of Dangeard and homologised the Vacuome with the Golgi apparatus. Guilliermond's subsequent contributions on the occurrence of Vacuome in plant cells will ever remain a work of classical importance. Parat and Painlévé took up the cue from Guilliermond's work in 1923, and described the occurrence of the Vacuome in animal cells for the first time by vital staining methods. As already stated above, they have since been able to homologise the Vacuome with the Golgi apparatus in animal cells. In 1924, A. Corti (21), a disciple of Golgi, demonstrated by a modified Regaud's method, the existence of vacuoles which he calls "Lacuonome," corresponding to the Vacuole described by Parat and Painlévé. N. Chlopin (1925) confirmed these ideas upon the liver of axolotl in tissue cultures.

Further, the examination of salivary glands, pancreas, etc., has led Parat to the conclusion that the apparatus of Golgi is constituted by a system of vacuoles (Vacuome) in which

"granules de secretion" are produced by condensation. These grains when formed lose their power of colourability by neutral red, which according to Parat is the best colourant for an *intra vitam* demonstration of Vacuome.

DISCUSSION.

The question now arises whether the Golgi bodies as revealed by the aid of the classical fixatives and the Vacuome so easily coloured by neutral red (colouration vitale) are one and the same structures, or are they different formations altogether. Lately I have been working in collaboration with Dr. Parat on the eggs of certain Ascidians[1] and Amphibians.[2] We injected neutral red into the epidermis first and afterwards intra-peritoneally quantities varying in all from 8 to 12 c.c. Within a few days the ovary becomes well impregnated with neutral red, and is ready for vital examination. Sometimes we have fed animals with neutral red through the mouth and we found they were none the worse for it. We made sketches and took microphotographs of our vital examination slides. We fixed ovaries by classical fixatives also. The methods that gave us complete satisfaction were those of Nassonow and Dietrich. We tried other classical methods also, but found that they caused distortion of Golgi bodies to some extent or other. By comparing the pictures obtained by vital staining and by the classical fixatives mentioned above, we found that the Golgi bodies in the animals examined by us, were invariably spherical in form never changing shape and occupy nearly the same space and relative position as the vacuoles (Vacuome) obtained by the vital and post-vital examinations. In the early stages of the development of the egg, these bodies occupy a juxta-nuclear position and along with the mitochondria generally form the characteristic crescent-shaped

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[1] Ascidia mentula, and Ciona intestinalis.

[2] Triton cristatus and Triton marmoratus ;
Alytes obstetricans ; Rana temporaria.

yolk-nucleus of Balbiani. In later stages this dense cloud disappears and the vacuoles (Vacuome) arrange themselves more or less in a peripheral layer.

Subsequent to my arrival in India last year, I set several of my pupils to work upon the cytoplasmic inclusions in the eggs of a variety of animals. We tried the usual classical fixatives and the *intra vitam* methods advocated by Parat (73) and Gatenby (39). In all the animals examined by us so far, *e.g.*, the common Indian earthworm (Pheretima posthuma (87), the pigeon (27) and a variety of other birds, the common Indian toad (57), Varanus and Lacerta, it was found that the Golgi bodies were spherical in shape, at least in the later stages of development. In earlier stages they are granular and their exact shape is difficult to determine. Ludford's latest modification of the osmic acid method (53) is undoubtedly the best fixative we could lay our hands upon. It has always given us satisfaction. A comparison of the pictures obtained by the usual fixatives and the wet methods of Parat and Gatenby lead me to think, firstly, that the Golgi bodies are spherical in shape, secondly, that the Golgi bodies and vacuoles (Vacuome) are homologous structures.

It is interesting to note here that in December, 1925, Nassonow in an interview, after a practical demonstration by Parat, in the department of Histology, Sorbonne, Paris, admitted that the latter's ideas as regards the Vacuome were substantially correct. Nassonow, however, thinks that the membrane of the Vacuome—which according to him is the homologue of the membrane of Protozoan excretory vacuoles (1924, 60) represents the Golgi apparatus. It seems to me that Nassonow is making a sweeping generalisation on the examination of a very specialized case, the one of the Protozoan with excretory vacuoles, which can hardly be homologised with all the other cells of Metazoa. I may also mention here that Vishwa Nath and his collaborators in a series of papers

recently published (61, 63) seem to be inclined to the view that the Golgi bodies are ring-like or spherical in shape. Vishwa Nath (62, 63) seems to have a distinct leaning towards Parat's Vacuome theory. The Vacuome theory has already been admitted by Corti and N. Chlopin. It appears thus, that at least in certain animals (*vide* the types mentioned above), the well-known Golgi bodies and the Vacuome of Parat, Painlévé and Guilliermond are very likely homologous structures and are always spherical in form. More work on the above lines on a large number of types is urgently needed to put an end to the interesting controversy that has been raised as regards the homology of the Golgi body and the Vacuome, by the important contributions of the above-mentioned French Cytologists.

CONCLUSION.

The examination of cytoplasmic inclusions in the oogenesis of a number of animals, leads me to conclude :

(1) That the Golgi bodies are granular and acquire a juxta-nuclear position in the early stages of development of the egg.

(2) That the juxta-nuclear Golgi complex is probably the result of the Golgi bodies and the mitochondria running together under the influence of strong fixatives and thus producing artefacts.

(3) That in the later stages of development the Golgi bodies are spherical in shape.

(4) That the Golgi bodies and vacuoles (Vacuome) of Parat and Guilliermond are very likely homologous structures.

(5) That so far as fixatives are concerned the shape of the Golgi bodies is best preserved by Kolatchev-Nassonow method, and Ludford's latest modification of the osmic acid method.

(6) That the neutral red technique of Parat is undoubtedly the most convincing of all the methods for the demonstration of vacuoles (Golgi bodies).

(7) That the homology of the Golgi body with the Vacuome can only be established by examining side by side slides made by the *intra vitam* method and classical fixatives.

TECHNIQUE.

For vital staining, it is essential that a very good quality of neutral red is used. 1/500 neutral red (Krall) in 6/1000 physiological salt solution, in proportion of 1 to 500 volumes respectively is placed in bath at 38°C. for 12 hours or so. The above should be mixed before use with an equal part of Janus green 1/500 in 6/1000 salt solution. Sea water replaces Janus green equally well. Janus green by itself is not a good specific either for Golgi bodies or even for the detection of mitochondria for after a quarter of an hour it becomes harmful and causes vesiculisation and fragmentation of the chondriome. By prolonged action it can colour Vacuome also, and thus confusion between the two structures is caused. What are generally labelled after such an examination as Golgi bodies, may in reality be Vacuome or Golgi bodies together with broken-up and vesicularised fragments of Chondriome. Neutral red is, however, a specific for Golgi bodies, for it colours Golgi bodies alone and nothing else. Even granules of secretion when fully formed are not coloured by it. Soon after the Golgi bodies are coloured by neutral red, Janus green can be introduced under the cover slip cautiously. Generally within a quarter of an hour, sometimes after prolonged treatment, mitochondria make their appearance. They do not, however, last long, and as I have already said fragmentation and distortion sets in. The stage may be very transitory and short-lived. Only a close application and diligent search under the high power of the microscope will show it. It sometimes happens that mitochondrial filaments become visible, but as soon as the class is called to witness the great event, the green colour disappears and disappointment results.

Fixatives used :—

(1) Nassonow modification by Parat and Painlévé

$K_2Cr_2O_7$	...	3 %	...	2 vols.
Acid, Chromic	...	1 %	...	2 vols.
Acid, Osmic	...	2 %	...	1 vol.

Fix for 6—24 hours; wash in water 18—24 hours; transfer to Osmic acid 2% for 12 days; sections to be cut 3—5μ thick. Bleaching by Henneguy's method; staining by Altmann-Kull technique.

Henneguy's bleaching method is very useful for removing the blackness of over-osmicated material. It consists in washing slides rapidly before staining in a 1% aquous solution of potassium permanganate, and afterwards in a 4% solution of oxalic acid. The bleaching should be controlled under the microscope. Sometimes over-osmication is an advantage for in certain cases, Golgi bodies take in their characteristic black colour, long after the fat bodies have been blackened.

(2) Dietrich after Parat and Bergeot.—

Fix in Regaud's fluid (bichromate-formal) or better still in Helly's fluid for 24 hours; afterwards in a saturated solution of potassium bichromate at 38°C. in the bath for 48 hours; wash in water for 12 hours; stain in haematoxylin.

Haematoxylin in a little alcohol	...	1 gr.
Solution acid acetic 2% in water	...	100 c.c.

Differentiate in Potassium ferricyanide solution of Weigert. This method gives a negative result for Golgi bodies, for their presence is indicated only by vacuoles whereas lipoids such as mitochondria and yolk are stained black.

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ON THE BEHAVIOUR OF THE GOLGI APPARATUS IN THE OOGENESIS OF CALOTES VERSICOLOR (BOULENGER)

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CONTENTS.

1. INTRODUCTION.

The abundance of Reptilian types in India affords a vast field for cytological research. For some reason or other, not much work has yet been done from the modern cytological point of view on this group. Dr. Bhattacharya (3) worked out the Cytoplasmic Inclusions in the Oogenesis of certain Tortoises and Lizards. It was with a view to fill up this gap, that the present work has been undertaken at the instance of Dr. Bhattacharya. This paper, therefore, attempts only to give a preliminary account of certain Cytoplasmic Inclusions in the Oogenesis of the common Indian lizard, Calotes versicolor. A general review of the formation and behaviour of Cytoplasmic Inclusions in various groups of Reptiles is in course of preparation, by one of us (S. K. D.). Calotes offers an ideal type for work of this kind as it is found in abundance and keeps well in captivity for a very long time.

The work was originally undertaken by one of us (S. K. D.) till the other author (J. J. A.) who had been independently working on the same problem arrived at Allahabad, with a view to completing the work under the guidance of Dr. Bhattacharya in the Zoological Laboratory of the University of Allahabad. As both the authors happened to be working on the same problem, and at the same time, it was suggested that they should collaborate. The major portion of the work was thus done at Allahabad.

We have pleasure in recording here our sincere thanks to Dr. Bhattacharya for his kind advice and criticisms during the course of the work, and for offering us all facilities in looking up literature on the subject.

2. MATERIAL AND TECHNIQUE.

The material consisted of ovaries from thirteen female lizards. The time taken in the taking out of ovaries and putting them in the fixatives never exceeded a couple of

minutes. This naturally precluded the possibility of the cytoplasm undergoing appreciable disorganisation.

The ovaries were fixed in two lots—one by Da Fano's (7) Cobalt-Nitrate method and the other by Ludford's (14 and 15) latest modification of the Osmic method. Luckily these two methods gave us the desired results, although we tried several other methods also.

Sections 6μ in thickness were cut in the case of material fixed by Da Fano's method and 4μ thick in the case of the material fixed by the osmic technique. Serial sections were made of both kinds of material.

Silver sections were toned and stained in Safranine and Light Green which did not always prove very successful. The remaining slides were stained in Iron Haematoxylin which gave very satisfactory results. Both toned and untoned slides were also mounted unstained for purposes of comparison.

Ludford's technique gave us excellent results. The time for post-osmication was prolonged to three weeks, since one week was found to be rather insufficient for our purpose. The Golgi bodies in this animal seem to be less osmiophile and a little over-osmication proved advantageous. This material was bleached by Henneguy's method in 1% aqueous solution of potassium permanganate and afterwards in 4% solution of oxalic acid. Sections were treated for various lengths of time in turpentine to remove the fatty substances, and afterwards stained by the Champy-Küll technique (18). Unstained slides before being treated by turpentine showed fatty yolk admirably.

We tried also the Intra-vitam method as suggested by Parat (22) but did not meet with much success.

3. THE DISPOSITION OF THE GOLGI BODIES IN THE OOCYTE AND IN THE FOLLICULAR EPITHELIUM.

In the young oocyte the Golgi apparatus acquires the usual complex form as a compact massive structure situated

adjacent to the nucleus (Figs. 1, 2, 3, 4). In silver preparations it takes the form of a very dense mass of minute spherical or disc-shaped granules (Figs. 1 and 3) lying in a comparatively denser area which has been described by D'Hollander (6), Gatenby (8 and 9), Bhattacharya (3), and others as the "Yolk nucleus of Balbiani." This area in subsequent stages acts as a focus of growth and dispersal of Golgi bodies. It is probably homologous with the centrosphere area which Brambell (2) shows so clearly in the bird. We have, however, found no trace of a centrosphere in this area. Another peculiar and unusual feature was the presence of two such areas juxtanuclear in position lying on opposite sides (Fig. 3). A reference to the photomicrograph of Figure 3 will show that one of these Golgi foci is larger than the other. Whether the smaller one originates independently of the other or is a part of the older and larger specialised area (yolk nucleus), we are unable to tell, as we have not been able to find any intermediate stages.

Brambell (2) in the bird has shown the occurrence of several such foci in the oocyte of a six weeks old chick and described it as an abnormal arrangement of Golgi bodies.

The osmic preparations also revealed the same structures with this difference that the second small patch of yolk-nucleus(?) or denser archoplasmic area was not found in any of the stages examined by us (Fig. 4).

Under high power the Da Fano sections show the presence of a dense area apparently packed-full of Golgi bodies, inside the yolk-nucleus region, surrounded by a comparatively lighter area (Fig. 3). The exact shape of the individual Golgi bodies inside the denser area is difficult to make out even under the high powers of the microscope (Fig. 3, G_1).

At this stage the dispersal of Golgi bodies from the original focus goes on at a rapid pace. All traces of the two denser areas soon disappear. The cytoplasm acquires a homogeneous appearance with the Golgi bodies which now appear as granules, distributed all over its surface. It appears thus,

that the Golgi bodies after acquiring a certain amount of growth undergo disruption into dust-like particles, now innumerable in number. This period also marks the zenith of the formation of fatty yolk described elsewhere. The Golgi bodies tend to become smaller and smaller in the medullary region of the egg, but in the peripheral region a cortical layer of larger Golgi bodies becomes regularly arranged. Golgi bodies large enough to be visible under the low powers of the microscope are not found outside this peripheral region of the egg.

At about this stage or even a little earlier the follicular epithelium seems to embark on a phase of great activity so far as the Golgi bodies are concerned. Golgi granules are seen to mass together in the cells of the follicular epithelium adjacent to the Zona Radiata. Then they are expelled from the cells and pass on their way to the egg through the Zona Radiata which in Da Fano preparations appears as a strikingly transparent space between the follicular epithelium and the egg. (Fig. 6). Regular stages of the Golgi granules passing from the follicular epithelium to the egg can be observed in various places under the high powers of the microscope (Photomicrograph Fig. 6). Once arrived at the cortical region of the egg they seem to confine themselves mostly to this region. The innumerable dust-like particles of the Golgi bodies in the cortical region of the egg give it a very characteristic appearance and afford a great contrast with the transparent medullary region of the egg in slides treated with turpentine. The ultimate fate of the cortical layer of the Golgi bodies is difficult to trace out as they tend to become irregular in shape and break up into ultramicroscopic particles.

4. FORMATION OF YOLK.

At the early stages of development inside and around the yolk-nucleus area small fatty droplets begin to make their appearance *pari passu* with the growth and dispersal of the Golgi bodies in this area. These fatty droplets begin to increase

in number and spread themselves out throughout the cytoplasm. On a close observation under the high powers of microscope it is found that these fatty droplets undergo development in close association with one or more Golgi granules. Sometimes Golgi granules are found situated on the surface or on the rim of a developing fatty droplet; while occasionally they may be found even inside the substance of these fatty discs or spherules. It is difficult to say whether the Golgi bodies undergo direct transformation into fatty yolk or whether in some indirect way they contribute towards the formation of these fatty droplets or yolk. These fatty droplets reduce osmic acid easily and acquire the black colour very readily. They are also easily decolourized in turpentine thus making it possible to differentiate between these and the larger Golgi bodies. There seems to be little doubt that these black spherules which Ludford (16) calls fatty droplets and Gatenby and Nath (9) identify as fatty yolk are ultimately derived either directly or indirectly from the broken-up Golgi bodies.

True yolk bodies, though apparently fewer in number, in the stages, so far available to us, also make their appearance at a stage when the yolk nucleus of Balbiani disappears and the fatty yolk is fairly well established. As the short time at our disposal did not allow us to use specific mitochondrial technique, we are not in a position to say definitely about the origin of true yolk. In Ludford slides stained according to Champy-Küll technique, beautiful patches of mitochondria stained red are visible. In certain cases some of these red granules appear to have become inflated and become converted into yolk bodies, while in others growth takes places inside a vacuole. In the absence of more convincing proofs, we are unable to press this point any further.

5. DISCUSSION.

It appears to us that the silver technique undoubtedly brings about great distortion of cell-organs, for instance, the

Golgi bodies which appear more or less spherical at a certain stage in Ludford preparations appear rather distorted and irregular in shape in the corresponding stages in Da Fano preparations. The characteristic network found in the Da Fano preparations in the yolk-nucleus area are absent in osmic preparations. We may mention here that really good osmic must be used, and all details of the technique strictly adhered to, in order to get the best picture. In such osmic preparations, it is found that the yolk-nucleus area is packed-full of Golgi granules which give it a very dense black and massive appearance. The network or branched appearance or even irregular large bodies so commonly met with in Da Fano preparations are entirely absent. In later stages when the Golgi bodies spread themselves out in the cytoplasm their shapes both in Da Fano and Ludford preparations are granular. At a still later stage the Golgi bodies grow up and arrange themselves as a distinct ring-like layer in the periphery of the egg. In Da Fano preparations these bodies appear distinctly irregular in shape and are several times bigger than the Golgi granules in the medullary region. In Ludford preparations at a similar stage of oogenesis, the Golgi bodies in the peripheral layer are spherical in form though much larger than the Golgi granules of the medullary region. This fact leads us to think that the shape of the Golgi bodies is better preserved in Ludford's osmium technique than by Da Fano's Cobalt-Nitrate method.

The subsequent history of the Golgi bodies is the same as in most of the vertebrate animals; they undergo disruption, become granular and finally lost to view in the cytoplasm.

The follicular epithelium appears to play an important rôle at a certain stage in the development of the egg. The individual cells become active and a large number of Golgi granules are expelled to the cortical region of the egg. Whether they pass through a definite channel in the Zona Radiata or in a haphazard manner, we have been unable to

4

trace; but we found both in our Da Fano and Ludford sections a number of Golgi granules lying in various regions of the Zona Radiata.

As we worked with a large number of ovaries the chances of an artefact seem to be remote. Since these granules, react to the fixatives we have used in the same way as the Golgi bodies inside the egg, we infer that they must be similar structures. Such extrusions of Golgi bodies from the follicular epithelium to the egg have already been noted and described in detail by Bhattacharya (3) and Brambell (2) in the tortoise and the fowl respectively.

Vishwa Nath (20) in a series of papers published recently has tried to show that the fatty yolk is invariably formed from the Golgi bodies either directly or indirectly. So far as Calotes is concerned we feel inclined to the view that the Golgi bodies are responsible in some way or other for the formation of what may be called the Golgi Fatty Yolk. Instances are not wanting of the formation of the fatty yolk by Golgi bodies, *e.g.*, in Saccocirrus described by Gatenby (8) in Lithobius, Julus and Palamnaeus by Vishwa Nath (9 and 20) and in Oniscus by Miss King (11). Ludford (16) describes the formation of fatty yolk even in the cells of tissue cultures from Golgi bodies. He calls them fatty or lipoidal droplets. Curiously enough the method of formation of the fatty droplets described by Ludford is very similar to that of the fatty yolk in Calotes.

As we had no idea of extending the scope of work beyond the examination of Golgi bodies in the animal studied, we did not use specific methods for the detection of mitochondria. But Ludford's osmic technique combined with Champy-Küll staining does show mitochondria as well. We found in slides stained by this method certain stages in the development of mitochondria. At a particular stage mitochondria appeared in patches throughout the cytoplasm. In close proximity to and even sometimes

inside the patches various stages in the development of true yolk bodies have been found. In certain cases it was observed that mitochondria swell up and gradually lose their affinity for the stains. In a later stage of development the swollen mitochondria were observed to lie inside vacuoles (Fig. 7). The development appears to be very similar to that described by Brambell (2) in the fowl.

Neither the nucleus nor the general cytoplasm appears to take a direct part in the formation of true yolk.

6. SUMMARY.

1. In the young oocyte of Calotes the Golgi bodies appear as a complex dense mass in the usual juxtanuclear position and consist mainly of granules.

2. In later stages the Golgi bodies become scattered in the cytoplasm and gradually become ultramicroscopic in the medullary region of the egg. In the peripheral region comparatively bigger Golgi spherules arrange themselves in a ring as a cortical layer. Subsequently with the development of the egg they are broken up and lost to view in the general cytoplasm.

3. At a particular stage of development the follicular epithelium becomes very active and a large number of Golgi spherules appears to be extruded from the epithelial cells to the egg. They pass through the Zona Radiata and settle down in the extreme peripheral region of the egg where they are indistinguishable from the original Golgi spherules of the developing oocyte.

4. The Golgi bodies either directly or indirectly contribute to the formation of yolk.

5. Mitochondria are probably solely responsible for the formation of true yolk.

7. EXPLANATION OF PLATES.

Photomicrographs of sections showing the Golgi bodies were taken under high power, using the combination of Zeiss 12X Kompensokular and Zeiss Apochromatic objective—these two yielding a magnification of 1500. The photographic plates used were Orthochromatic ½ size plates and the exposure given was 45 seconds. It was found necessary to over-expose the plates a little to get a sharp contrast of images.

The drawings were made under Leitz Abbe Camera Lucida (12X ocular; 1/12th oil immersion).

Fig. 1.—Transverse section of the ovary of Calotes fixed in Da-Fano toned and stained in Safranine and Light Green. The young ovum shows the juxtanuclear Yolk-nucleus packed-full of Golgi bodies. The larger eggs show the peripheral arrangement of Golgi granules. (Low power.)

Fig. 2.—A fairly big oocyte showing the juxtanuclear Golgi. Fixed in Ludford and stained by Champy-Küll method. Patches of mitochondria are visible. (Low power.)

Fig 3.—Photomicrograph showing two juxtanuclear Foci (G1 and G2). The scattering of the Golgi granules in the cytoplasm from one of the foci (G3) is also visible. Fixed in Da Fano, toned. X1500.

Fig 4.—Photomicrograph showing one juxtanuclear focus of Golgi bodies. Fixed in Ludford. (Low power.)

Fig 5.—Photomicrograph showing one juxtanuclear focus of Golgi bodies fixed in Ludford. High power X1500.

Fig 6.—Photomicrograph showing the migration of Golgi bodies from the follicular epithelium into the peripheral cytoplasm of the egg. High power X1500.

Fig. 7.—The structure of the cytoplasm and the formation of yolk. The Golgi bodies giving rise to Golgi fatty yolk. True yolk discs lying inside a vacuole are derived from the adjacent mitochondrial patch. High power X1900.

Lettering—F.—Follicular epithelium. GFY—Golgi fatty yolk. G—Golgi bodies. G1—The first focus of yolk-nucleus. G2—The second focus of yolk-nucleus. G3—The scattering Golgi granules in the cytoplasm from the yolk nucleus. M—Mitochondria. MTY—Mitochondrial yolk or true yolk.

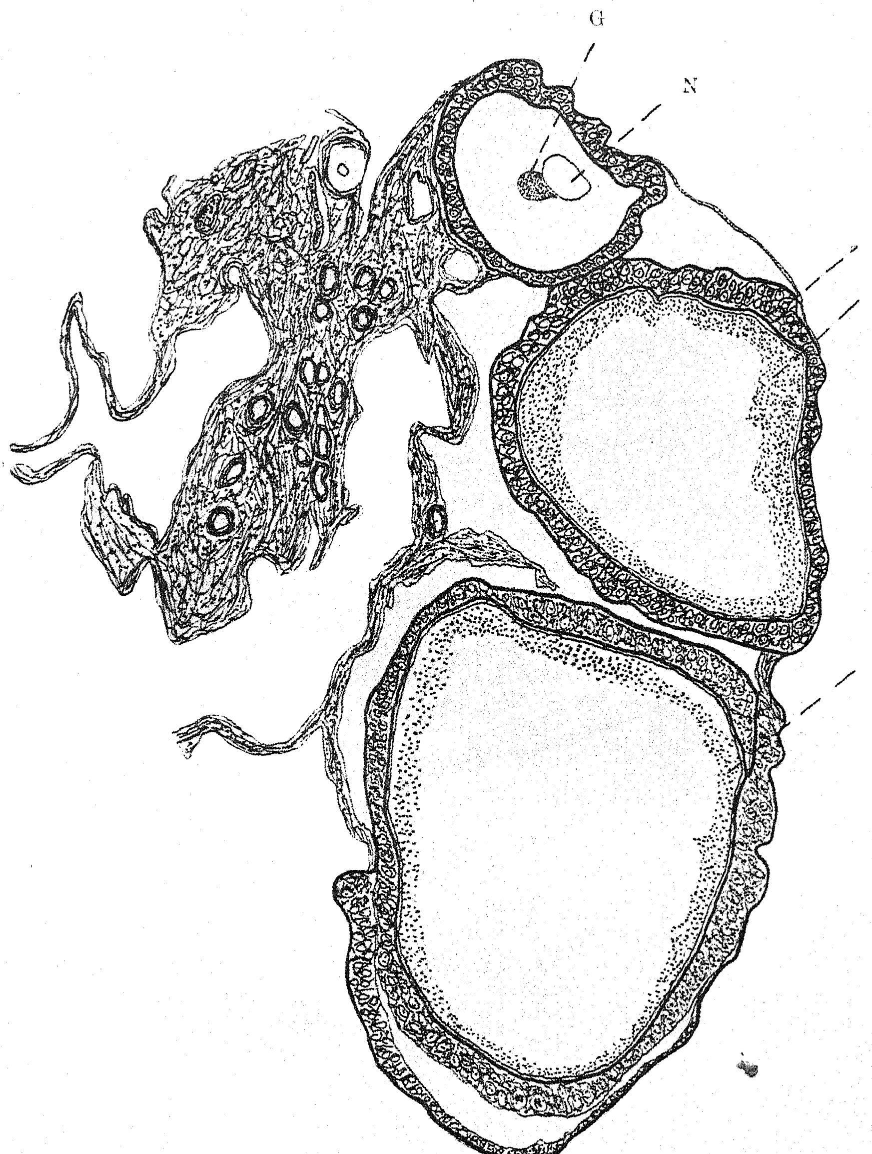


FIG. 1.

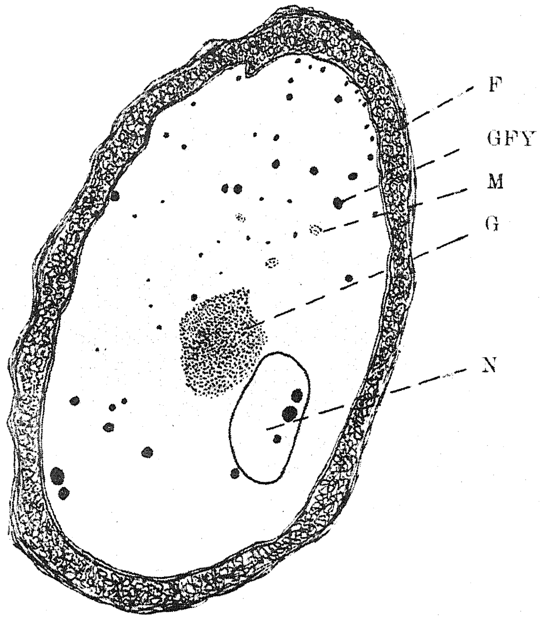
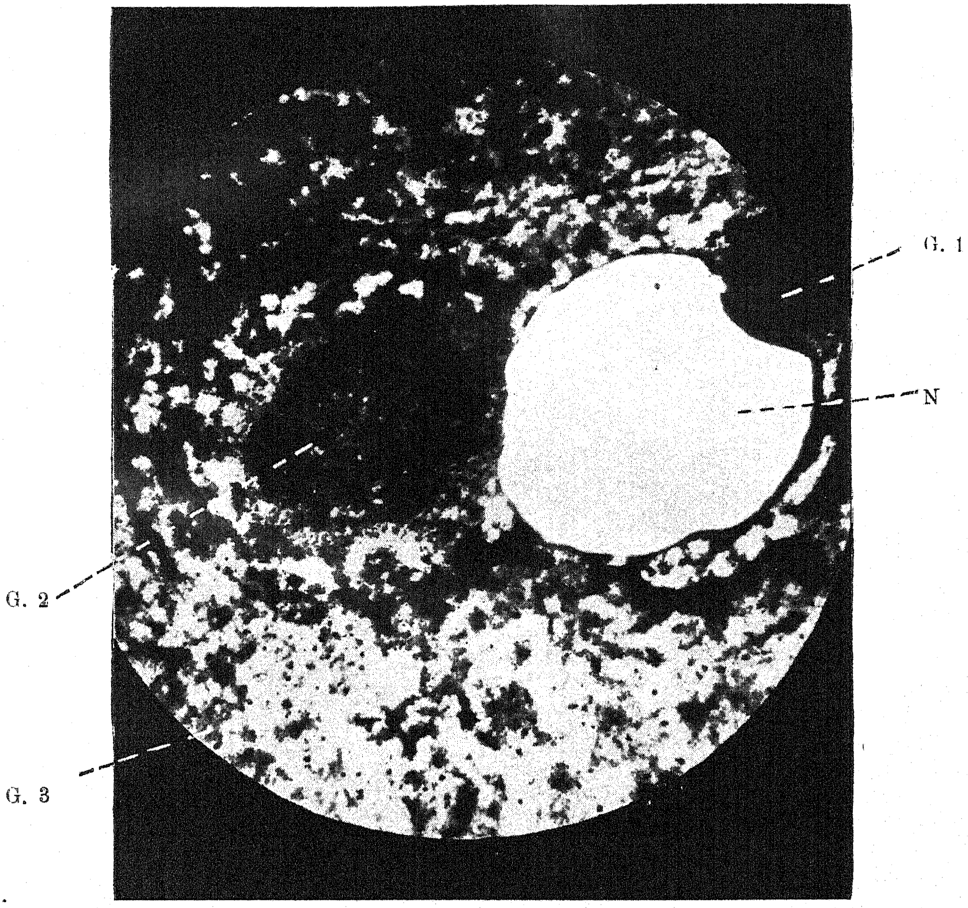


Fig. 2.



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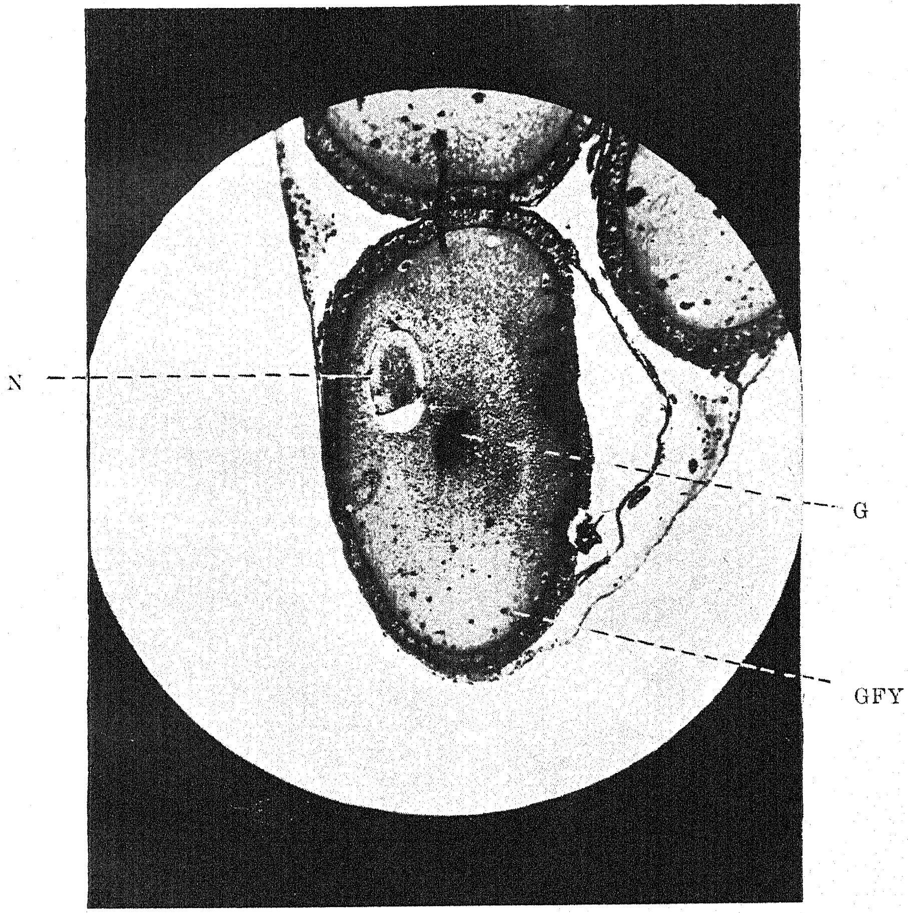

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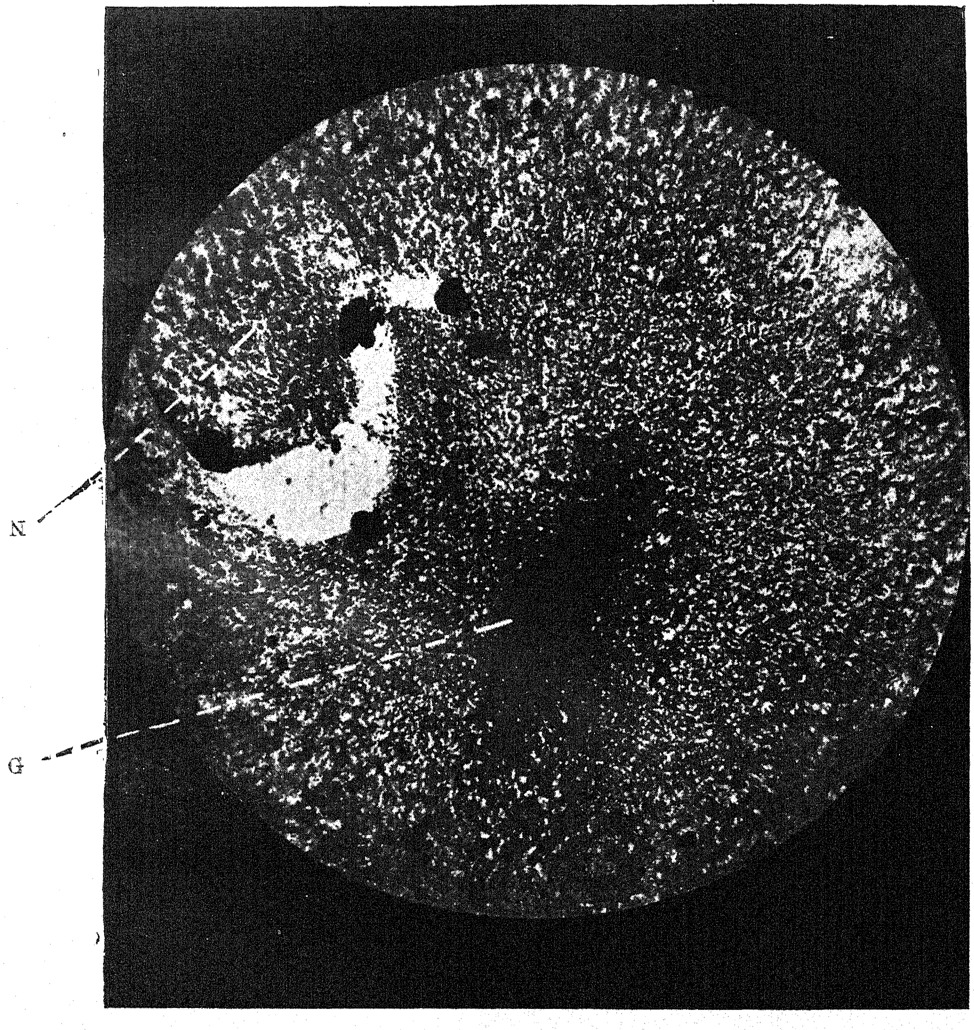

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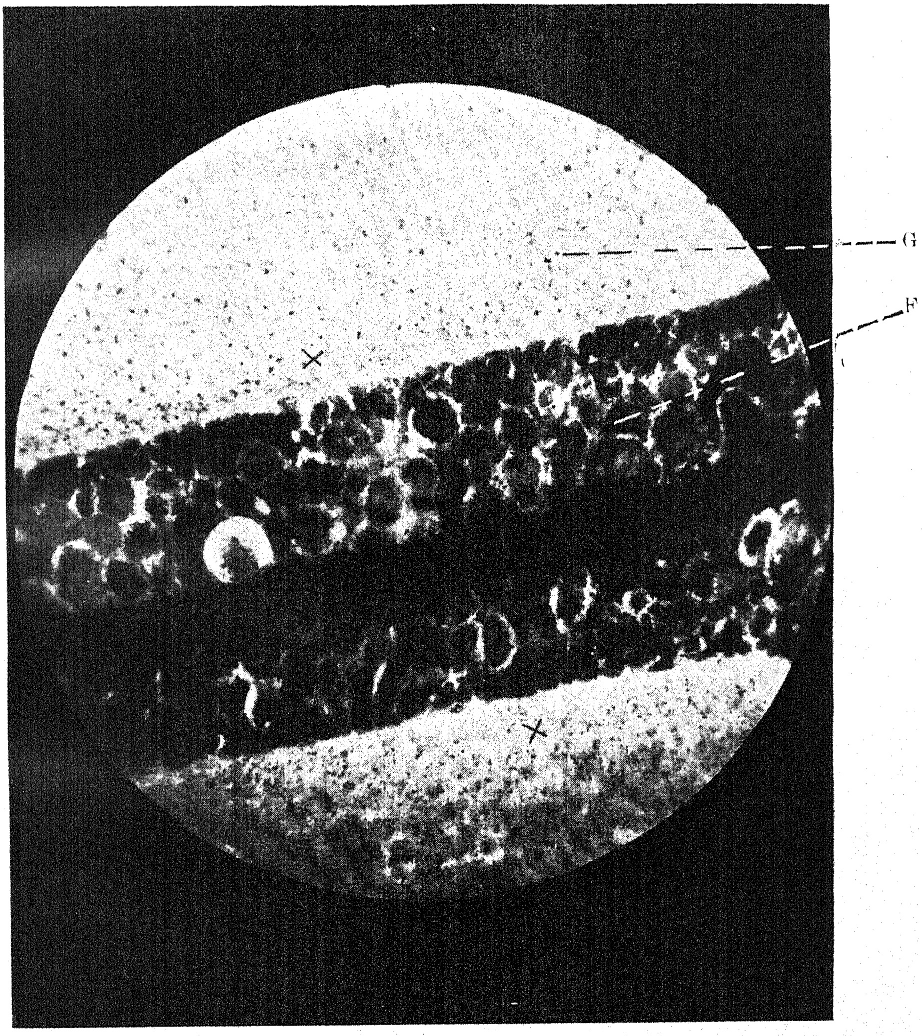

× Infiltration

Fig. 6.

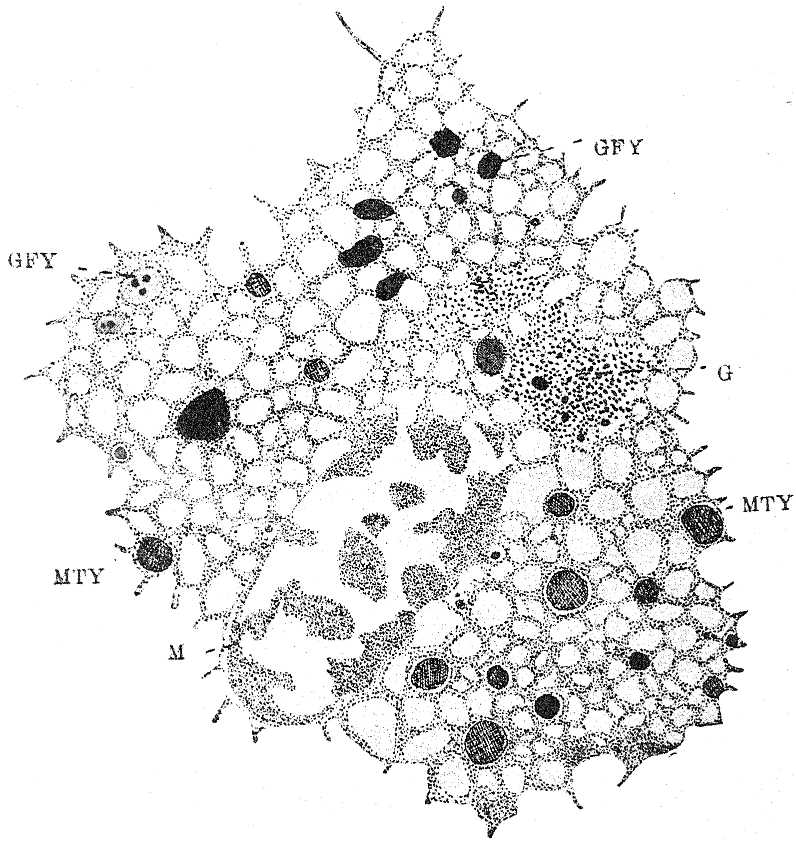

FIG. 7.

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A PRELIMINARY ACCOUNT OF THE CYTOPLASMIC INCLUSIONS IN THE OOGENESIS OF COLUMBA INTERMEDIA.

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CONTENTS.

INTRODUCTION.

The justification for undertaking this work arises on account of the fact that India is so rich of Avian fauna, and not much work from the point of view of modern cytology, beyond that of a nice monograph on the oogenesis of the fowl by Brambell (2), has yet been done. This paper purports to give only a preliminary account of the oogenesis of Columba intermedia (the common Indian rock pigeon), which I am using as a type. In a subsequent paper, I intend to publish my observations on a large number of birds belonging to different genera and to submit therein a comparative account of cytoplasmic inclusions.

Among the previous workers on the subject, Mlle. Loyez (9) in 1905 gave a detailed account of oogenesis of Reptiles, Birds and Cephalopods. Her interesting contribution loses much of its charm because of the fact that she took no account of certain cell organs which form the subject-matter of this paper. The technique for the detection of such cytoplasmic inclusions

was not well understood then and was probably not known to her. In 1914, Dr. Van Durme (20) published an extremely interesting paper on the oogenesis of birds. She described in detail the origin and development of Mitochondria and also of yolk bodies. Her paper also is vitiated by the fact that she ignored the existence of one of the most important cytoplasmic inclusions—the Golgi bodies. This omission has subsequently (1925) been rectified by an important contribution on the oogenesis of the fowl by Brambell (2). In order to supplement the knowledge already gained by Brambell's work, Dr. Bhattacharya suggested to me to undertake to write a monograph on the oogenesis of birds in general, from the point of view of cytoplasmic inclusions. As the work will take about 2 years to accomplish, it was thought desirable to publish this preliminary account, starting with Columba intermedia, as a type.

This work has been carried on under the guidance and supervision of Dr. D. R. Bhattacharya. I wish to express here my deep sense of gratitude for the keen interest which he has shown throughout the progress of this work and for kindly correcting the manuscript of this paper.

MATERIAL AND TECHNIQUE.

The pigeon (Columba intermedia) used in this work was killed by severing the head without the use of an anæsthetic. The ovaries were taken out as quickly as possible and put into the various fixatives. The whole process from the killing of the animal to the fixing of the ovary did not take more than three minutes. Thus the chances of post-mortem changes were reduced to a minimum. The following methods of fixation were used in connection with this work :—

1. Da Fano's cobalt-nitrate modification ; cold fixation.
2. Ramon Y Cajal's uranium nitrate and silver nitrate method ; cold fixation.

3. Latest modification of Mann-Kopsch osmic method by Ludford.
4. Flemming without acetic acid.
5. Regaud's formol bichromate method.
6. Regaud-Tupa's uranium nitrate formol bichromate method; cold fixation.
7. Bouin's picro-formol method.
8. Champy's method modified by Nassonov and later by Parat; cold fixation.
9. Carnoy's method.

The cold method consists in fixing the material inside an ice-box for periods recommended for each fixation. By carefully comparing the results it is found that the cold fixation methods gave by far the best results. One great advantage of cold fixation is that it allows of little shrinkage to ova. The fixative remains in a good condition at about 0°C. for a much longer time than otherwise, and therefore the action of the fixative on the tissue is more of the desired nature.

The ovary of the pigeon is extremely osmiophile, and it is unsafe to leave the material in 2% osmic acid for more than three days. In summer 36 hours are quite enough. If kept longer, the material becomes brittle and requires plenty of bleaching. Osmic acid at room temperature works well but if kept in a hot bath as recommended by Ludford, Champy and others, the acid as well as the material soon gets spoilt—the material becoming disintegrated and powdery. Possibly the hot climate of Northern India in summer has something to do with it. In the course of my experience with the pigeon material, I found that sections from osmic preparations should always be treated with turpentine for 5 to 10 minutes in order to dissolve away the fat and that the turpentine must invariably be of the purest variety and not acidic. Similarly the sections should always be mounted in pure Canada balsam (Baume du Canada) which should always be kept in the dark. The xylol-balsam generally used and kept carelessly

exposed to light and air is always acidic and in a very short period reduces the intensity of the osmic colour. The acidity of turpentine and balsam should always be tested with phenolphthalein. The litmus paper reaction should never be relied upon. I wish to lay stress on this point particularly as I believe that carelessness in using the right kind of turpentine gives erroneous results and produces artefacts. I used a sample of turpentine obtained from a firm in India, and I found that in less than 2 minutes the entire sections were bleached with the result that it became impossible to trace the existence of Golgi bodies.

For purposes of intra vitum examination very young ova were thoroughly teased out of the ovary in salt solution (6/1000 dilution) and examined in neutral red solution (1/500 in 6/1000 salt solution). Very young oocytes were also examined in a mixture of equal parts of neutral red and Janus green B (1/500 in 6/1000 salt solution) (17).

Ovaries were also teased out in salt solution and examined after the addition of a few drops of 2% osmic acid according to the method recommended by Gatenby and Nath (7).

DESCRIPTION.

The Golgi Bodies.—The Golgi apparatus in the pigeon can easily be demonstrated both by osmic and silver nitrate methods. In the oogonium it lies close to the nucleus in the form of a minute knot-like body. In these oogonia the constitution of the Golgi complex is difficult to determine, as at this stage the entire apparatus is made up of a dense little mass. As the oogonium develops into an oocyte, this mass begins to spread itself out in a semi-lunar fashion. In still bigger oocytes the apparatus forms a little cap-like structure on one pole of the nucleus. In certain oocytes a binuclear condition is found and in such cases the Golgi apparatus occupies the space between the two nuclei. In later

stages the Golgi bodies begin to spread themselves out around the nucleus and occupy a perinuclear position. In subsequent stages they seem to disappear altogether and their place is taken up by what look like swollen Golgi bodies or fatty yolk discs. Fatty yolk formation at this stage is very intense and Golgi bodies are found only in the periphery as a ring of minute granular bodies. A noticeable thing is that the Golgi bodies after emerging from the juxtanuclear mass always appear as spherical bodies and are never irregular in shape if properly fixed.

By the intra vitum examination method advocated by Parat (17) with neutral red the young oocytes were seen to possess a juxtanuclear patch of minute spherical bodies which take in the characteristic red colour. According to Parat (18) these bodies are what he calls Vacuome, and are homologous with the Golgi bodies demonstrated by the classical methods.

Migration of Golgi Bodies.—Both in the silver (particularly Cajal) and osmic preparations after proper toning or bleaching as may be necessary it is easy to demonstrate the Golgi bodies in theca and epithelial cells. In theca cells the Golgi apparatus lies on one side of the nucleus and is in the form of a little tiny dense compact mass. Such bodies I believe travel later to the follicle cells and from there to the oocyte. The following observations are in favour of the above statement:—

1. The cells of theca interna immediately outside the follicular cells have very prominent Golgi bodies. At places it may be seen that the Golgi bodies of several adjacent theca cells arrange themselves in a very regular way facing the follicular epithelium. At this stage they are very minute in size, and at places can be seen actually passing into the follicle cells.

2. At certain places it may be seen that an exactly similar row of Golgi bodies as described above occupy the outer zone of follicle cells. It seems probable that these have been imported from outside, *i.e.*, from theca cells.

3. Still, at other places, the transference of Golgi bodies from the follicle cells into zona striata is observable. The Golgi spherules forming radially streak-like rows between the follicular epithelium and the cortical layer of the eggs can be seen in several places if carefully searched under an oil immersion lens. These Golgi granules derived from the egg membranes form a dust-like cortical layer in the extreme periphery of the egg. Whether the Golgi granules present in the cortical layer are solely derived from this source or also from the original Golgi apparatus of the egg is difficult to understand.

4. The peripheral layer of Golgi bodies makes its appearance after the juxtanuclear Golgi mass has disappeared.

Mitochondria.—The mitochondria are best studied by the Regaud-Tupa and Champy methods. They make their first appearance as little granules lying close to the nucleus. In developing oocytes the granules appear as a dense cloud in a juxtanuclear position. Subsequently the mass breaks up and the mitochondria become dispersed throughout the cytoplasm. Mitochondrial activity reaches its zenith at this stage and the whole cytoplasm becomes full of mitochondria. Definite layers or zones of mitochondria such as those described by Brambell (2) in the fowl, excepting one in the extreme periphery, were not observable.

Yolk.—As referred to above, the Golgi bodies at a very early stage acquire a fatty nature and become converted into fatty yolk-discs or vacuoles or droplets. In Champy preparations, in young oocytes, the entire cytoplasmic area appears full of black fatty material. In a later stage the dense fatty mass becomes resolved into black disc-like structures scattered throughout the cytoplasm. As the cell grows older the medullary region becomes clear, and these fatty discs arrange themselves in a peripheral ring-like zone. This layer gradually travels towards the extreme periphery, with the growth of the oocyte. There seems little doubt that these bodies have been directly or indirectly formed from Golgi bodies.

The true yolk appears to be formed from mitochondria. In Champy preparations a gradual swelling of mitochondria can easily be observed. These swollen mitochondria, in most cases, become enveloped in vacuoles and undergo further development therein. This process of conversion of the mitochondria into yolk bodies seems to take place mostly when the former lie at the periphery of the egg. The process is very much the same as that described by Van Durme (20) in birds, by Brambell (2) in the fowl, and by Bhattacharya (3) in tortoises. Champy preparations were stained by the Champy-Küll method. The mitochondria become stained red and yolk-discs appear to have a deep brown colour. The various stages in the conversion of mitochondria into yolk bodies are not difficult to follow.

SUMMARY.

1. The Golgi bodies acquire the usual juxtanuclear position in the early stages of development at one pole of the nucleus. Later on they take a perinuclear position and are soon replaced by a fatty yolk layer.

2. The Golgi bodies of the cells of the egg membranes at a particular stage seem to acquire unusual activity and travel through the zona radiata into the cortex of the egg. Here they arrange themselves into a dust-like cortical layer of extremely minute granules. What further part they play in the development of the egg is uncertain.

3. Mitochondria in the early stages form a cap-like dense cloud over one pole of the nucleus. Subsequently they become distributed throughout the cytoplasm. In older oocytes a peripheral zone of mitochondria becomes noticeable.

4. In very young oocyte fat droplets or yolk become a characteristic feature of the developing oocytes. The perinuclear layer of the Golgi bodies is soon replaced by the fatty yolk which appears to have started formation even when the Golgi apparatus lies in the region which is generally designated as the yolk-nucleus of Balbiani or the dense protoplasmic area adjacent to the nucleus. There seems little doubt that the Golgi bodies become directly or indirectly converted into fatty yolk or what others call fatty vacuoles or droplets.

5. True yolk appears to be formed by the direct metamorphosis of mitochondria inside a vacuole. Neither nucleus nor cytoplasm appears to take a direct part in the formation of the true yolk bodies.

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ON ECHINORHYNCHUS SP. INQ. FROM COMMON CROWS, CORVUS CORAX AND CORVUS SPLENDENS, OF ALLAHABAD

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The two common species of crow, Corvus corax and Corvus splendens, found at Allahabad are generally infected with Echinorhynchus sp. inq. Out of 24 crows shot in January, 1926, 18 harboured this parasite in the posterior part of their intestine. They are firmly attached to the wall by recurved spines on the proboscis, while their bodies hang freely in the lumen of the gut. All the worms are generally found attached in one part of the intestine within 2 or 3 inches of its length. Only in two cases I found them living away from others. One specimen however was found near the cloaca, *i.e.*, about 4 inches away from the others which existed in the intestine. The infected portion of the intestine after it was slit open was shaken vigorously in water for some time in order to separate the parasites from the wall but they did not detach. The proboscis in fully mature specimens is so deeply fixed that it is not easy to separate it from the wall. Deep wounds are caused in the wall at the points of attachment after the parasites are carefully separated.

The proboscis is oval in shape and studded with spines which are arranged in 28—30 rows each comprising 8—12 spines. On account of its deep penetration rounded ulcers are produced

on the outer surface of the intestinal wall, by the presence of which it becomes easy to recognise the infected portion of the intestine. Specimens of smaller size, however, do not produce such ulcers. The body which hangs freely in the lumen of the gut appears generally shrunken and shows marks of external annulation. These marks, however, disappear and the body becomes smooth after death or after the live worms have been kept in salt solution for some time. They perform sluggish movements by contracting and expanding the body, but they cannot move in a particular direction even for a short distance. They have been generally observed not to live for more than 4-5 hours in salt solution. In a crow dissected 18 hours after it was shot 3 out of 15 specimens were found living. When the specimens died in the body of the host they separated from the wall and were found in a straightened condition floating among the contents of the gut.

The length varies according to the age from 16—24 mm. and the breadth from 2—4·5 mm. The male specimens are always smaller and less broad as the measurement given in tables 2 and 3 of the male and female specimens respectively will show. The body is cylindrical somewhat tapering towards both ends. The posterior extremity is blunt and rounded while oval proboscis forms the anterior part, which can be completely retracted into the proboscis sheath. The neck in this species is absent. Southwell and Macfie (1925) define the neck as that portion which lies between the base of the proboscis and the anterior end of the body. Its presence or absence is of great importance in the systematic study. In the worm under description there exists only a constriction at the base of the proboscis between it and the body but there is no distinct neck (Figs. 1—3).

Proboscis (Fig. 4) is oval in shape and 2 by 1·5-2 mm. in size. It is armed with rows of fine recurved hooks which are radially and symmetrically arranged. The proboscis can be ordinarily retracted in a hollow muscular bag with double

walls—the proboscis sheath. "The term 'Proboscis' is applied to that process at the anterior extremity of the body which is used as an organ of fixation" (Southwell and Macfie, 1925).

The spines (Figs. 5 and 6) are chitinous. They are radially arranged in regular circular rows. The number of rows varies from 28—30 in an individual and the number of spines in a row from 8—12. The spines in the middle of the proboscis are longer and stouter. They are simple having a recurved shape with a thick base and fine-pointed end. The base passes invariably into the chitinous platform of a rectangular outline which remains embedded in the skin, which covers generally the basal portion of the spines also (Figs. 5—7). Tables 2 and 3 give measurements of the spines.

The colour of the body is olive throughout its length in the male specimens but in the female it is greenish, while in fixed ones, it is grey with some dull black patches in the middle of the body.

The body wall (Fig. 10) consists externally of a thin layer of cuticle under which lies the thick subjacent hypodermis. The hypodermis consists of a fibrous tissue with no definite outlines in which there lie scattered many groups of prominent and a few groups of small nuclei. It is traversed by a system of canals forming a regular network, known as the Canalicular System (Fig. 9), with a few big longitudinal canals and a large number of fine anastomosing branches. The canals are filled with a semi-fluid substance and in sections of the worm appear in the form of innumerable cavities or chinks. Inwards to submucosa there lies a layer of longitudinal muscle fibres followed by a layer of circular muscle fibres, then follows a thick layer of spongy fibrous tissue which is full of irregular cavities. Hamann considers it to be composed of elastic fibres and a viscid gelatinous connective substance. A regularly broken layer of thick-walled hollow muscular fibres which in sections present the appearance of cut tubes, forms the innermost part.

On each side of the proboscis sheath there lies a muscular fold which arises from the anterior end of the worm just behind the constriction at the base of the proboscis. These two structures are called Lemnisci (Fig. 11), which being continuation of the body wall are composed mainly of the subjacent hypodermis and the muscular layers. As their length varies in different genera, their measurements are of some importance from the systematic point of view. The proportion of their size to that of the body is subject to variation owing to the contracted and expanded state of specimens during fixation.

The proboscis sheath (Fig. 11) is a hollow bag hanging inside the body cavity. It is composed of two layers of muscle fibres similar to those of the body wall. At its posterior end are attached a certain number of long muscular bands which extend backwards and are attached to the body wall at different lengths in the middle third portion of the body. They constitute what is known as the motor apparatus of the proboscis, which is a finger-shaped hollow process of the body wall. This motor apparatus exists obviously for its protrusion and retraction.

The male genitalia (Fig. 13) consist of 2 testes, vasa efferentia, vas deferens, seminal vescicle, prostate glands, penis, and bursa. The 2 testes, which are nearly equal in size, are oval in shape and lie one behind the other in the anterior one-third of the body behind the lemnisci. The anterior testes is situated about 3-4 mm. behind the anterior end of the body. Their length varies from 1·25-1·80 mm. and breadth from 0·7-1 mm. in fully mature specimens. An efferent duct is given out from each testis to carry its contents. The vasa efferentia which arise one from each testis run along the sides of the latter for some distance before they join to form the vas deferens. The vas deferens is a long thick tube with a constriction in the middle, presenting a dumb-bell-shaped appearance with the anterior end more swollen. It gradually narrows towards the posterior end to form the muscular penis in which

it ends. Its length varies from 1·6-2.5 mm. The prostate glands are 6 rod-like structures closely attached to one another. They do not arise at the same place; on the other hand their points of commencement vary. The first gland arises just behind the posterior testis which it sometimes touches, while the second arises a little behind. The third and the fourth arise together at the same level a little further back. Situated alongside of first and second, the fifth arises on the ventral surface near the middle of the mass formed by the four prostates mentioned above and running for a short distance ends above the seminal vesicle. But before it terminates the sixth prostate takes its origin. All the six glands ultimately unite together to open ventrally at their posterior extremity into the vas deferens, just in front of the opening of the vesicula seminalis into the latter. The histology of the prostate gland will be described in a subsequent paper. It may be mentioned here that the glands appear as solid elongated structures, the large central portions of which are filled with a granular secretory substance and the walls are mainly composed of a thick connective tissue layer (Fig. 15).

The seminal vesicle is a pear-shaped structure with thin walls, which opens on the right side near the extremity of the vas deferens, *i.e.*, at the origin of the penis.

The genital organs with their ducts and the prostate glands are all covered by a thin membrane of connective tissue which becomes thicker having a regular circular outline in the region of the vesicula seminalis.

The terminal part of the vas deferens passes into the penis, which is conical and has thick muscular walls. It seems that the penis is not the main copulatory organ. With the help of the bursa, to be described presently, it reaches the vagina of the female, into which it ejects the semen in the final stage of sexual congress.

The Bursa (Fig. 7) is a cuticular funnel-shaped structure which normally lies in a retracted condition in the body

cavity. During copulation or when the animal is pressed it is ejected entirely appearing like a bell-shaped structure bounded at the end by fine frills. The penis hangs within it at the top. Two sac-like structures, called the Sacs of the Bursa, are situated one on each side near the base of the penis on the inner side of the bursa in its everted condition. During mating the bursa is thrust into the vagina and so helps the short penis to deposit the discharge at a suitable place without spilling it outside the body of the female.

The Ovary is present only in young specimens. At the end of the post-larval stage it bursts liberating the egg masses (Fig. 8) which float about in large numbers in the body cavity. The egg masses give rise to the innumerable ova which in sexually mature specimens congest the body cavity forming its main contents. An egg mass is an elongated, more or less elliptical or oval body which is composed of a sheet of cytoplasm containing egg cells at various stages of development (Fig. 22). It is covered outside by a thin connective tissue layer. The eggs found in the body cavity are not at the same stage of maturity. The mature eggs (Fig. 23) are distinguished by the presence of three concentric membranes as their walls and hooks arranged in a ring at the broader end of the embryo. They are brown in colour and have an elongated elliptical shape. Their size ranges from 0·042-0·066 by 0·016-0·028 mm.

The Bell or the Uterine Bell (Fig. 17), as it is sometimes called, is the anterior part of the oviduct which continues behind into the Uterus. It is attached by means of a ligament which arises from the posterior end of the proboscis sheath, called the Suspensory Ligament. Its posterior end passes through the cavity of the bell to be attached to its side walls. The total length of the genital apparatus (Fig. 16), from the commencement of the bell to the Vulva, is 1·45-2·6 mm. The bell is a muscular canal provided with apertures at both the ends. Its inferior (posterior) opening is in direct communication

with the body cavity. The anterior orifice takes up all material floating in the body cavity, egg balls or egg masses, immature and mature eggs. The lumen of the bell in the middle of its length is reduced considerably on account of a number of large cells which project into it from the walls. These cells are arranged in five pairs, 3 dorsal pairs of large and 2 lateral pairs of relatively small cells. Their arrangement is such that only ova of a certain size can pass through the lumen enclosed by these cells and enter the uterus, while those which are not allowed to pass through are returned into the body cavity through the inferior opening. This is a kind of sorting arrangement enabling only the mature ova to get out.

The uterus is 0·73-1·25 mm. long and 0·07-0·08 mm. broad. Its anterior end is funnel-shaped and is in continuation with the bell in front. It has thick muscular walls. Very large number of ova are accommodated in the lumen owing to the great expansion of the walls at certain time of the year, *i.e.*, about the month of January to March. After the ova are discharged the walls appear somewhat flabby. The uterus leads into a pear-shaped vagina, which is large anteriorly and constricted and narrow at its posterior end. It is 0·37-0·82 mm. in length and 0·1-1·3 mm. in breadth in its anterior portion and 0·07-0·08 mm. in breadth at its posterior end. Its walls are very thick and muscular and contain also large glands (the Vaginal Glands) (Fig. 20), with prominent nuclei, which surround the lumen and pour their secretion into it. The fibres of the muscular layer are arranged in a spiral manner around the lumen more or less like the diaphragm below the stage of the microscope. The vaginal canal is surrounded by sphincter muscles, the anterior one being situated just at the base of its broad portion and the posterior a little in front of the opening of the vulva. The vulva is surrounded by two large flat cells which control its opening. The posterior portion of the vaginal canal is so narrow that only one ovum can

pass through it at a time and the rest have to wait in the broad portion of the vagina till their turn comes.

The Nervous System consists of a single nerve cell situated deep within the muscular layer of the proboscis sheath, near the middle of its length. The nerve fibres known as retinaculi (Fig. 11), arising from it pass out through the body cavity to the body wall.

The character of the genus is as follows:—Worms with well-developed proboscis armed with spines arranged radially and symmetrically; presence of a proboscis sheath at the base of the proboscis, with double wall into which the proboscis can be retracted. Nuclei of the subcuticuli and lemnisci relatively small and numerous with a few groups of large nuclei; 6 prostate glands are present and central nervous system near the middle of the proboscis sheath.

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TABLE 1.

List of Specimens found in each Crow.

Date on which Crows were shot.	Name and No. of Crows		Total No. of Specimens.	No. of Males.	No. of Females.	REMARKS.
1926:						
9th January	Corvus splendens.	4	...	...	...	
" "	" "	2	3	...	3	All found living freely in the intestine of the host.
10th "	" "	4	...	...	...	

TABLE 1—(*continued*).

Date on which Crows were shot.	Name and No. of Crows.		Total No. of Specimens	No. of Males.	No. of Females.	REMARKS.
22nd January	Corvus splendens.	4	...	...	...	
25th ,,	,, corax.	2	12	4	8	
29th ,,	,, splendens.	1	13	4	9	
,, ,,	,, Corax.	1	2	...	2	
,, ,,	,, ,,	1	...	...	...	
,, ,,	,, splendens.	1	...	...	...	On the 29th January, all the crows were shot at the place where refuse matter of the town is thrown (near George Town).
,, ,,	,, ,,	1	..	...	...	
,, ,,	,, ,,	1	...	..	...	
,, ,,	,, ,,	1	..	...	...	
,, ,,	,, ,,	1	...	...	...	
12th February	,, ,,	1	...	...	...	
13th ,,	,, ,,	1	...	...	...	
12th March	,, ,,	1	1	...	1	
12th August	,, ,,	1	...	...	..	
14th August	,, corax.	1	10	1	9	
20th ,,	,, splendens.	1	12	6	6	
13th September	,, ,,	1	1	...	1	
27th October	,, corax.	1	3	1	2	
,, ,,	,, ,,	1	1	...	1	
,, ,,	,, ,,	1	2	1	1	
,, ,,	,, ,,	1	2	1	1	
,, ,,	,, splendens.	1	1	...	1	
,, ,,	,, ,,	1	...	...	...	
16th November.	,, ,,	1	...	...	...	
18th ,,	,, ,,	1	1	...	1	

TABLE 1—(*concluded*).

Date on which Crows were shot.	Name and No. of Crows.		Total No. of Specimens.	No. of Males.	No. of Females.	REMARKS.
25th November	Corvus corax	1	4	1	3	
13th December	,, splendens	1	1	1	...	
1927 :						
15th January	,, ,,	1	4	1	3	
21st February	,, ,,	1	6	3	3	
24th ,,	,, corax	1	15	6	9	
25th ,,	,, ,,	1	12	4	8	
,, ,,	,, splendens	1	1	1	...	
8th March	,, corax	1	...	...	...	All these crows were 1½ months old; were taken down from the nest; could not fly. The worms were at the earlier stage of maturity.
2nd May	,, ,,	1	1	1	...	
3rd ,,	,, ,,	1	...	...	...	
,, ,,	,, ,,	1	1	...	1	

TABLE 2.

Measurements of Male Specimens.

	Specimen Number.		1	2	3	4	5	6	7
1	Total length of specimens ...		16 mm.	16 mm.	22 mm.	17 mm.	18 mm.	18 mm.	17 mm.
2	Breadth ...	Below the Proboscis ...	0·5 ,,	0·5 ,,	0·5 ,,	0·5 ,,	0·5 ,,	0·5 ,,	0·5 ,,
		Region of testes ...	2·5 ,,	3·0 ,,	3·5 ,,	2·0 ,,	3·0 ,,	3·0 ,,	1·9 ,,
		Near the posterior region ...	2·0 ,,	2·2 ,,	2·0 ,,	1·5 ,,	2·0 ,,	1·8 ,,	1·5 ,,
3	Proboscis ...	Length ...	0·50 ,,	0·55 ,,	0·58 ,,	0·48 ,,	0·50 ,,	0·50 ,,	0·48 ,,
		Breadth ...	0·50 ,,	0·48 ,,	0·50 ,,	0·46 ,,	0·48 ,,	0·48 ,,	0·47 ,,
4	Proboscis sheath	Length ...	1·25 ,,	0·93 ,,	1·25 ,,	0·93 ,,	1·00 ,,	1·10 ,,	0·92 ,,
		Breadth ...	0·37 ,,	0·30 ,,	0·40 ,,	0·30 ,,	0·32 ,,	0·34 ,,	0·30 ,,
5	Spines ...	Number of rows...	30	28	30	29	30	30	30
		Total length ...	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.
		Breadth at the base ...	0·014 ,,	0·014 ,,	0·014 ,,	0·012 ,,	0·012 ,,	0·014 ,,	0·012 ,,
		Breadth at the anterior end ...	0·003 ,,	0·003 ,,	0·003 ,,	0·003 ,,	0·003 ,,	0·003 ,,	0·003 ,,
6	Distance of testes from anterior extremity		4 ,,	3·5 ,,	4 ,,	3·0 ,,	3·5 ,,	3·8 ,,	3·1 ,,
7	Testes ...	Ant. ... Length ...	1·25 ,,	1·80 ,,	1·60 ,,	1·8 ,,	1·7 ,,	1·6 ,,	1·9 ,,
		Ant. ... Breadth...	1·0 ,,	1·0 ,,	0·7 ,,	0·8 ,,	0·8 ,,	0·8 ,,	0·8 ,,
		Post.... Length ...	1·25 ,,	1·50 ,,	1·7 ,,	1·7 ,,	1·6 ,,	1·6 ,,	1·3 ,,
		Post.... Breadth...	1·0 ,,	1·0 ,,	0·7 ,,	0·8 ,,	0·8 ,,	0·7 ,,	0·8 ,,

TABLE 2.—(*concluded*).

	Specimen Number.		1	2	3	4	5	6	7
8	Prostate mass ...	Length ...	9·5 mm.	9·5 mm.	7 mm.	6 mm.	6 mm.	6 mm.	6·1 mm.
		Breadth ...	1·0 "	0·8 "	0·5 "	0·5 "	0·5 "	0·6 "	0·5 "
9	Seminal vescicle	Length ...	2·5 "	2·4 "	1·6 "	2·0 "	1·6 "	1·7 "	1·9 "
		Breadth Ant. ...	0·3 "	0·3 "	0·3 "	0·3 "	0·3 "	0·3 "	0·3 "
		Breadth Post. ...	0·2 "	0·2 "	0·2 "	0·2 "	0·2 "	0·2 "	0·2 "
10	Bursa ...	Length ...	1·5 "	1·6 "	1·0 "	1·0 "	1·5 "	1·5 "	1·1 "
		Breadth ...	1·5 "	1·3 "	0·6 "	0·8 "	1·5 "	1·5 "	0·9 "
11	Length of Penis ...	...	0·17 "	0·25 "			0·25 "		
	REMARKS. ...	...	Measurements taken from permanent preparations.		Fresh and unpressed.	Preserved.	Permanent preparations.		

TABLE 3.

Measurements of Female Specimens.

	Specimen Number.		1	2	3	4	5	6	7
1	Total length	... ...	22 mm.	24 mm.	23·5 mm.	21·5 mm.	23·5 mm.	23·5 mm.	24 mm.
2	Breadth ...	Below the proboscis	0·5 ,,	0·6 ,,	0·5 ,,	0·5 ,,	0·7 ,,	0·6 ,,	0·55 ,,
		Middle region ...	3·5 ,,	3·2 ,,	4·5 ,,	3·5 ,,	4·0 ,,	3·5 ,,	4·0 ,,
		Posterior quarter ...	2·5 ,,	2·5 ,,	2·8 ,,	2·5 ,,	2·5 ,,	2·6 ,,	2·5 ,,
3	Proboscis ...	Length ...	0·53 ,,	0·51 ,,	0·53 ,,	0·50 ,,	0·48 ,,	0·51 ,,	0·50 ,,
		Breadth ...	0·46 ,,	0·48 ,,	0·46 ,,	0·46 ,,	0 39 ,,	0·46 ,,	0·44 ,,
4	Proboscis sheath.	Length	1·49 ,,	1·44 ,,	1·41 ,,	1·41 ,,	1·42 ,,	1·44 ,,	1·42 ,,
		Breadth ...	0·39 ,,	0·37 ,,	0·39 ,,	0·37 ,,	0·39 ,,	0·37 ,,	0·39 ,,
5	Spines ...	No. of rows ..	30	28	29	30	29	28	30
		Length ...	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.	0·03 mm.
		Breadth at the base ...	0·016 ,,	0·016 ,,	0·015 ,,	0·015 ,,	0·015 ,,	0·016 ,,	0·016 ,,
		Breadth at the ant. extremity.	0·005 ,,	0·005 ,,	0·004 ,,	0 004 ,,	0·005 ,,	0·004 ,,	0·005 ,,
6	Lemnisci ...	Length	5·0 ,,	5·5 ,,	5·0 ,,	5·8 ,,	5·5 ,,	5·0 ,,	5·0 ,,
		Breadth	0·5 ,,	0·4 ,,	0·5 ,,	0·5 ,,	0·4 ,,	0·3 ,,	0·5 ,,
7	Genitalia ...	...	Not distinct	Not distinct	Measurement in Table 4, Sp. No. 5.		Measurement in Table 4, Sp. No. 6.		
	REMARKS ...		Creamy colour, black specks nearabout the middle of the body.						

TABLE 4.

Measurements of Female Genitalia.

	Specimen Number.		1	2	3	4	5	6	7
1	Vagina ...	Length	0·58 mm.	0·82 mm.	0·51 mm.	03·7 mm.	0·70 mm.	0·75 mm.	0·58 mm.
		Breadth, upper part	0·13 „	0·10 „	0·12 „	0·08 „	0·10 „	0·12 „	0·08 „
		Breadth, lower part	0·07 „	0·08 „	0·08 „	0·07 „	0·14 „	0·20 „	0·12 „
		Breadth of vulva ...	0·17 „	0·20 „	0·14 „	0·13 „	0·20 „	0·20 „	0·14 „
2	Uterus ...	Length	0·86 „	1·25 „	0·88 „	0·73 „	1·41 „	1·03 „	1·08 „
		Breadth ...	0·08 „	0·07 „	0·07 „	0·07 „	0·07 „	0·12 „	0·03 „
3	Bell ...	Length	0·66 „	0·53 „	0·55 „	0·35 „	0·66 „	0·66 „	0·66 „
		Breadth ...	0·20 „	0·27 „	0·29 „	0·17 „	0·24 „	0·26 „	0·26 „
	REMARKS ...	... ...	Mounted specimen.	Mounted specimen.	Mounted specimen.		Fresh specimen.	Fresh Sp. Uterus choked with ova.	Specimen with egg in the Bell and Vagina.

TABLE 5.

Measurements of Ova.

	Specimen Number.	1	2	3	4	5	6	7
1	Length	0·059 mm.	0·063 mm.	0·050 mm.	0·042 mm.	0·066 mm.	0·063 mm.	0·050 mm.
2	Breadth	0·027 „	0·028 „	0·026 „	0·016 „	0·025 „	0·028 „	0·026 „
3	REMARKS	They were all elliptical, blunt at both ends, 3 concentric layers of walls were seen and tuft of hooks at the broad anterior end. They were taken out from the body cavity, bell, vagina and uterus.						

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REFERENCES TO FIGURES.

asf—anterior sphincter muscles.
b—bursa.
brc—branching of the central canal.
bw—body wall.
c—cuticle.
cb—cells of the bell.
cc—central canal of the prostate gland.
cm—circular muscle fibres.
cw—concentric walls of the ova.

d—ducts of the vaginal glands.
df—vas deferens.
do—developing ova.
ef—efferent ducts.
egm—egg mass.
fga—female genital aperture.
fb—funnel-like opening of the bursa.
gs—granular secretion of the prostate glands.
io—inferior opening.

sb—sacs of the bursa.
sv—seminal vesicle.
spw—spongy portion of the body wall.
sp—spines.

l—lemnisci.
lg—ligament.
lm—longitudinal muscle fibres.

lmb—longitudinal muscle bands.
lp—principal lacunae or canal.
lu—lumen of the vagina.
ls—secondary or anastomosing canals.
lvc—lining of the vaginal canal.
mf—muscle fibres surrounding the genitalia.
mvw—muscles of the vaginal wall.
n—nucleus.
o—ova.
p—penis.
pg—prostate glands.
pr—proboscis.
prs—proboscis sheath.

psf—posterior sphincter muscles.

rb—rectangular base of the spine.
ut uterus.
utb—uterine bell.
uw—uterine wall.

v—vagina.

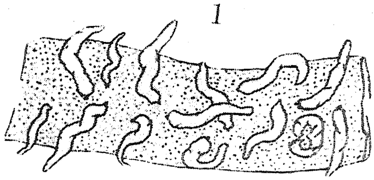
sm—spiral muscle fibres of the vaginal wall.
t—testes.
th—tuft of hooks or spines.
vgl—vaginal glands.
vp—muscular plate near vulva.

DESCRIPTION OF FIGURES.

1. A portion of the infected intestine of crow showing the worms attached.
2. Male Echinorynchus with bursa everted.
3. Female Echinorhynchus.
4. Anterior portion of the worm showing the proboscis, proboscis sheath and the arrangement of spines on the proboscis.
5. A portion of the proboscis magnified showing the arrangement of spines.
6. Spines with rectangular roots, taken out from the proboscis.
7. Posterior portion of the male worm showing ejected bursa, sacs of the bursa and penis.
8. Posterior portion of the female worm showing genital aperture, vagina, a portion of the uterus and egg masses.
9. A portion of the body wall showing principal lacunae or canal and secondary or anastomosing canals.
10. T. S. of the body wall showing the different layers.
11. Anterior portion of a female worm showing lemnisci, a portion of the proboscis sheath with the nerve fibres coming out from its middle part.
12. T. S. through the proboscis showing the spines, different layers of the body wall and proboscis sheath.
13. Male genitalia showing testes, prostate glands, efferent ducts, vas deferens, seminal vesicle, penis and bursa.
14. T. S. through the posterior region of the prostatic mass showing the relative position of the 6 glands.
15. T. S. of the prostate gland magnified showing the wall, central canal and its contents—the granular secretion.
16. Female genitalia showing bell, inferior opening, cells of the bell, uterus, vagina, sphincters and vaginal glands.
17. Bell magnified.
18. T. S. through the bell, passing through the middle region.
19. T. S. ,, ,, ,, ,, region of the inferior opening.

PLATE I

1



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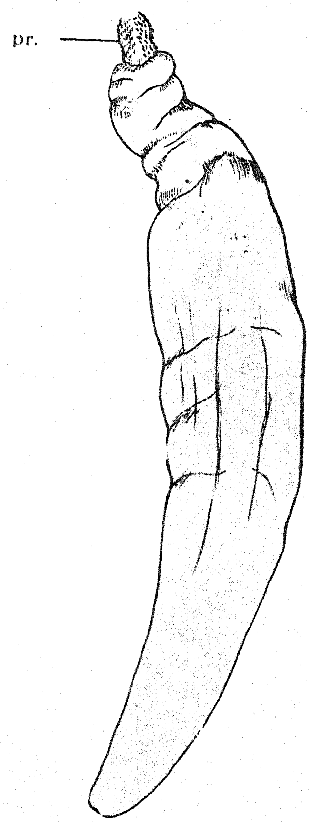

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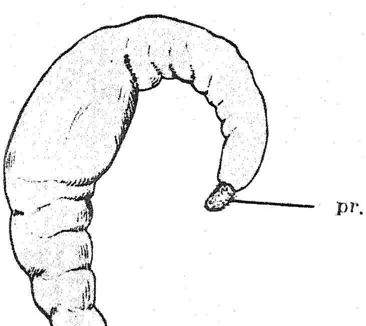

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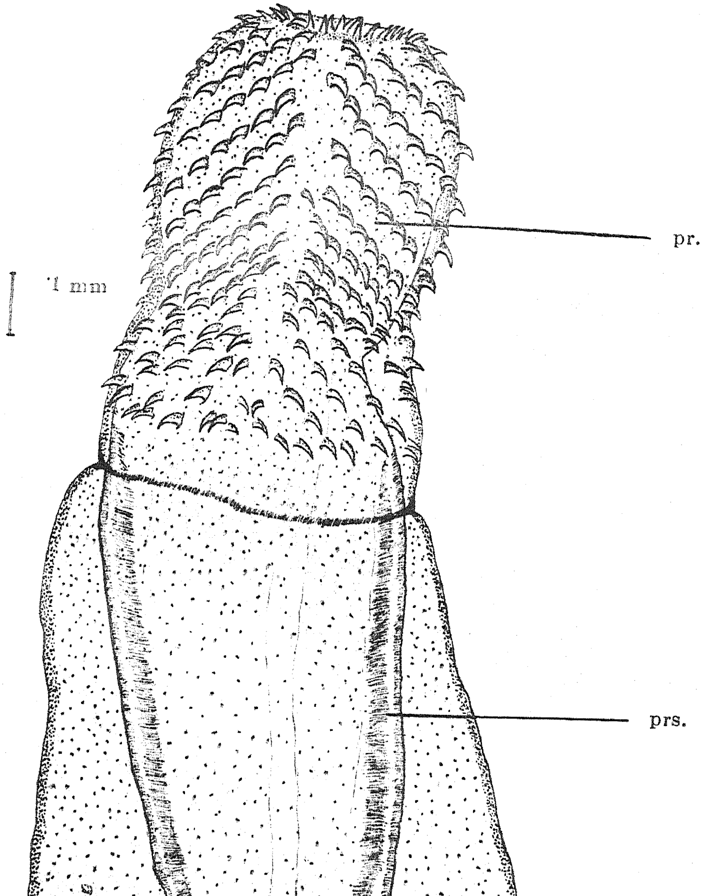
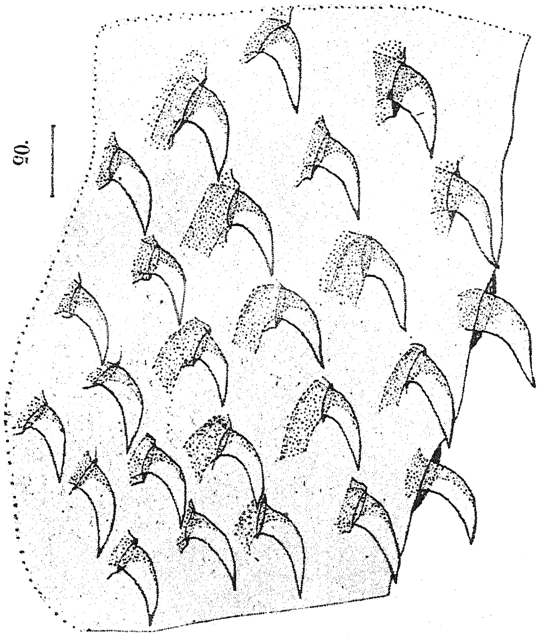


5. a portion of the proboscis showing the arrangement of spine

PLATE III



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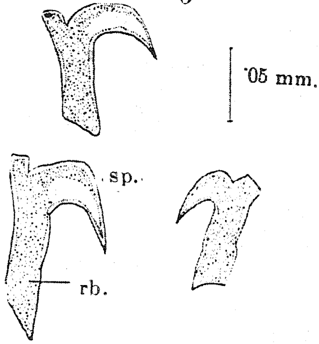

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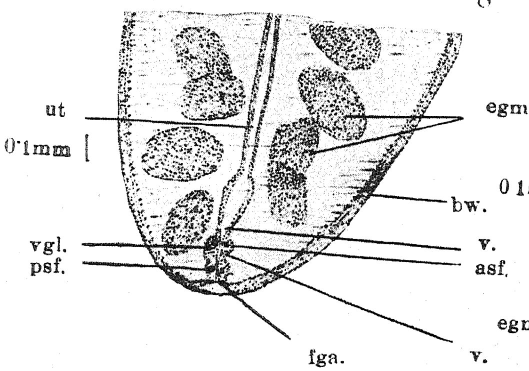

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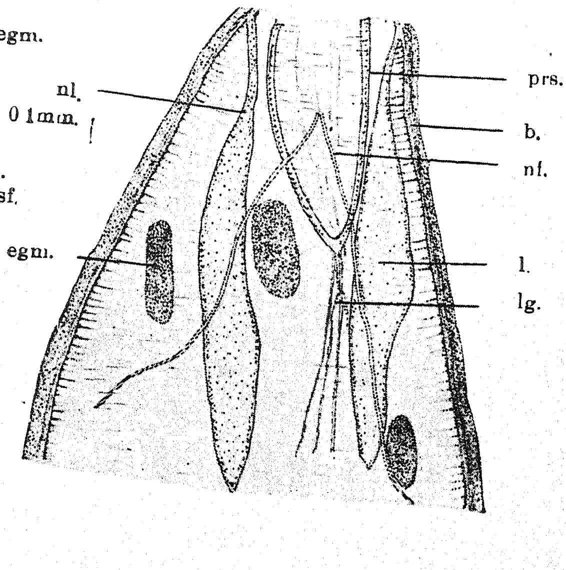

PLATE IV

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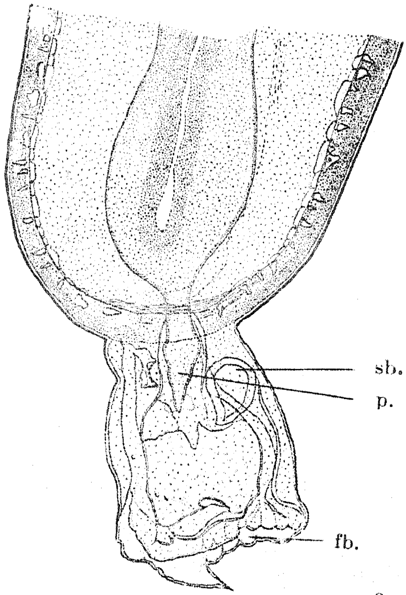

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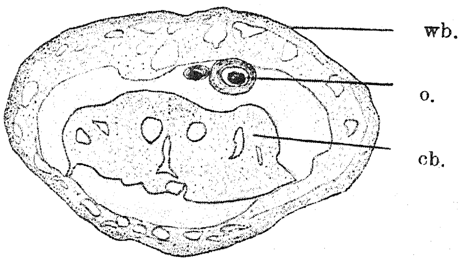

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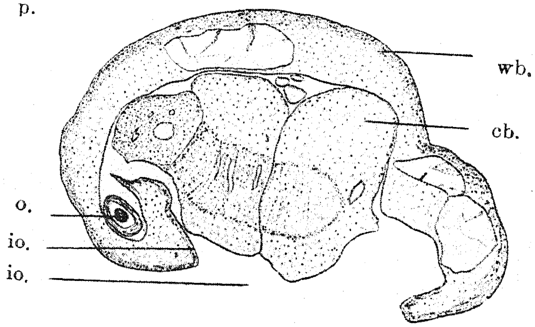

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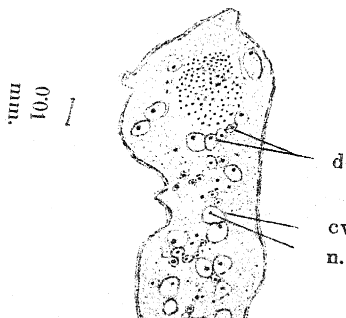

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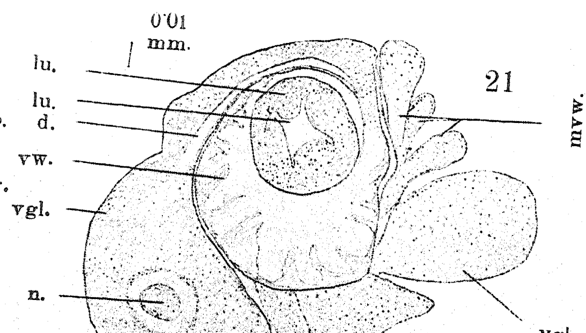

PLATE V

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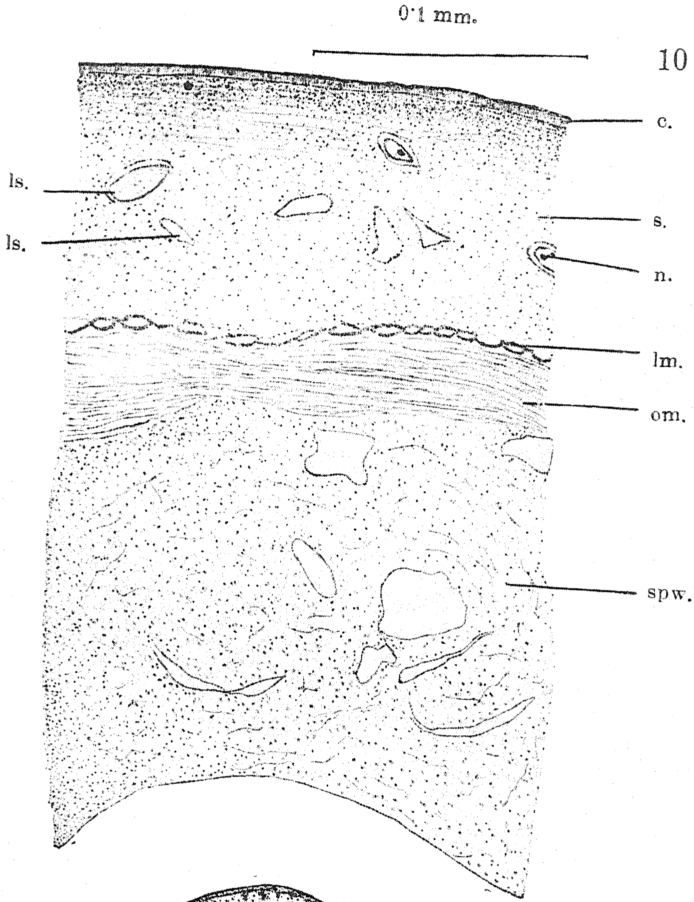

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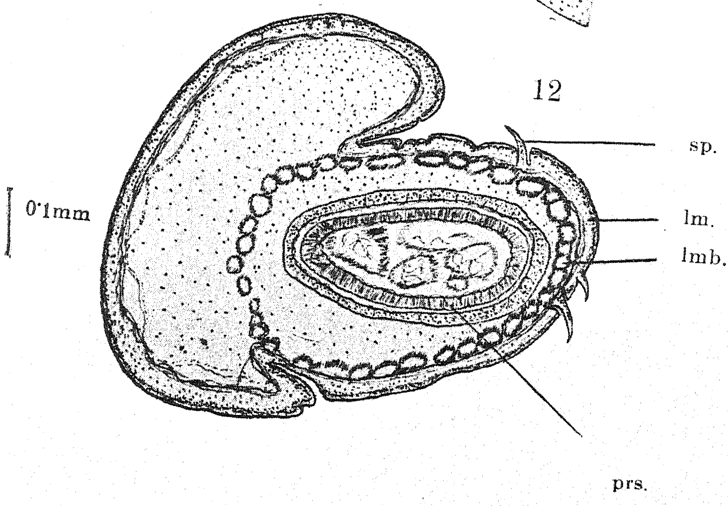

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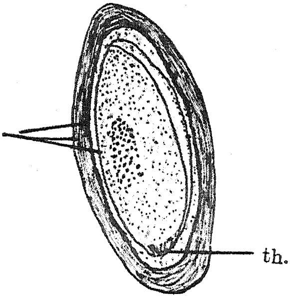

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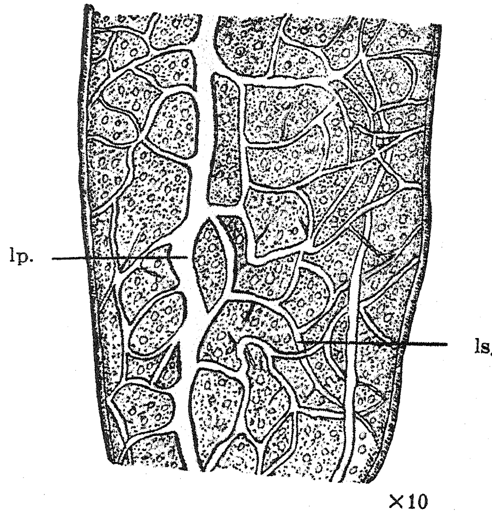

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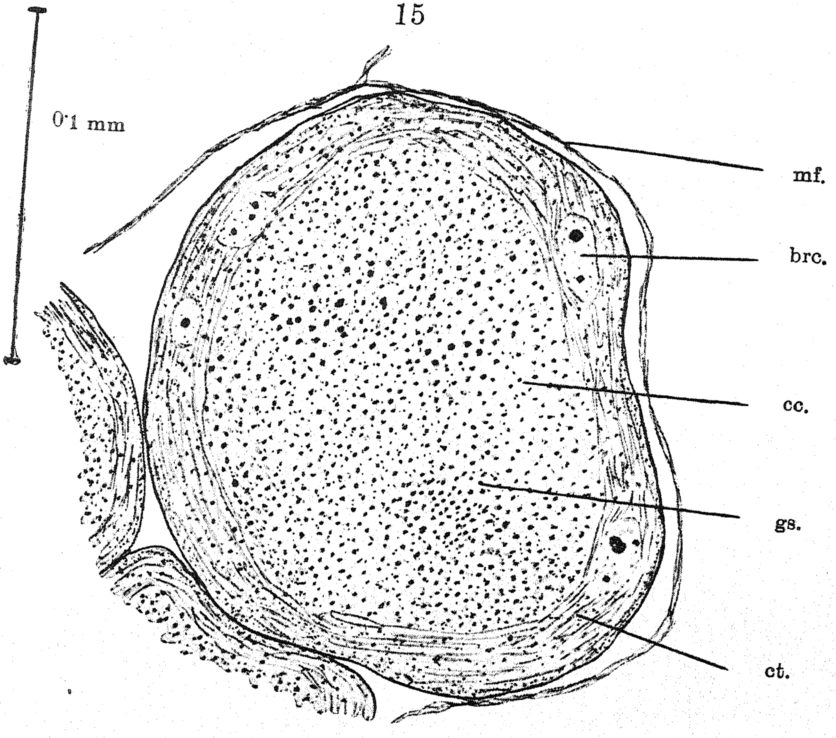

ct—thick connective tissue

PLATE VII

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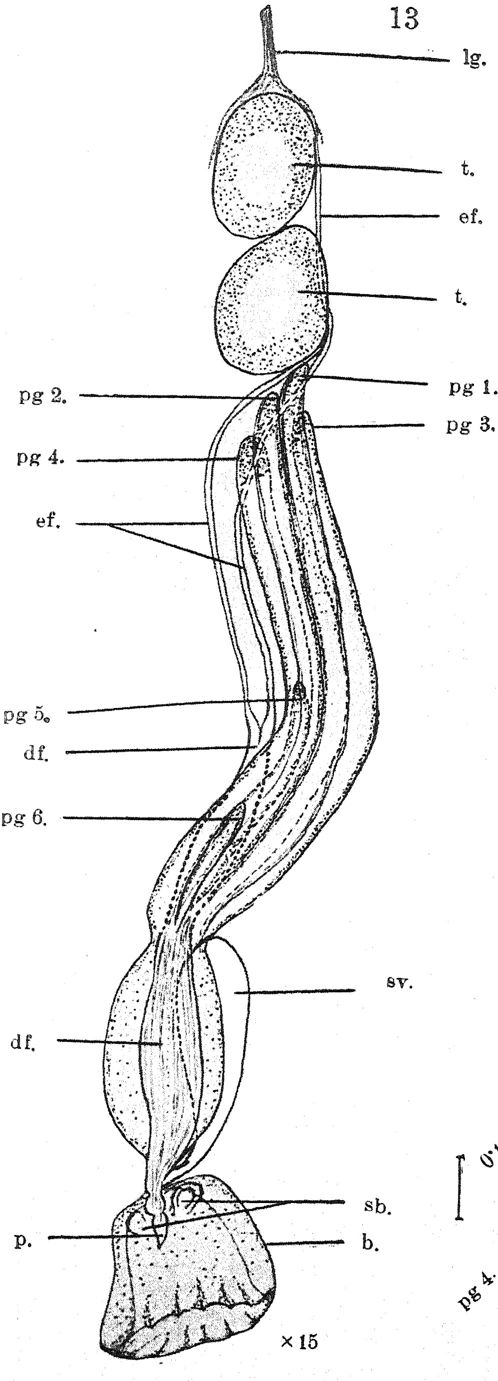

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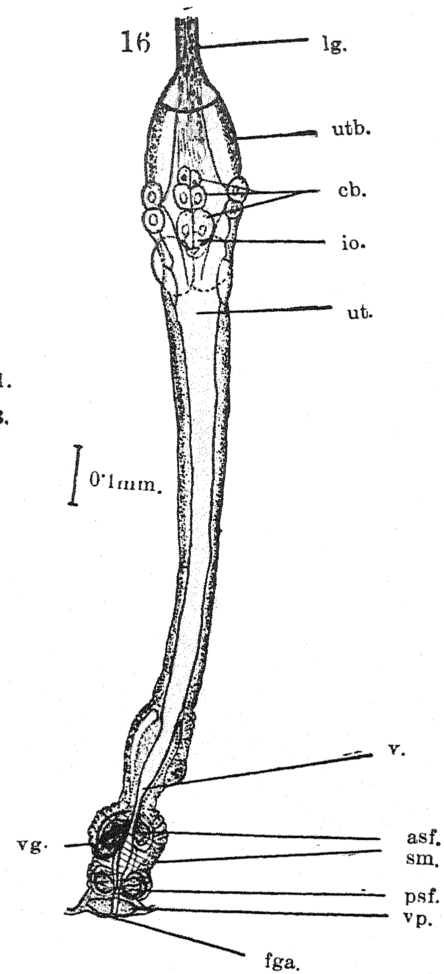

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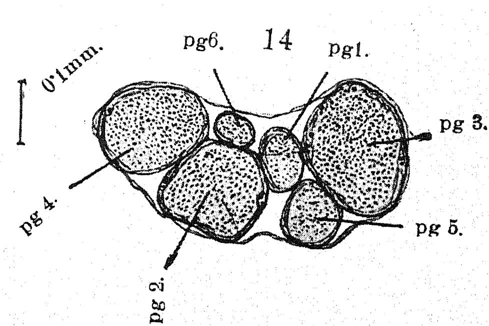

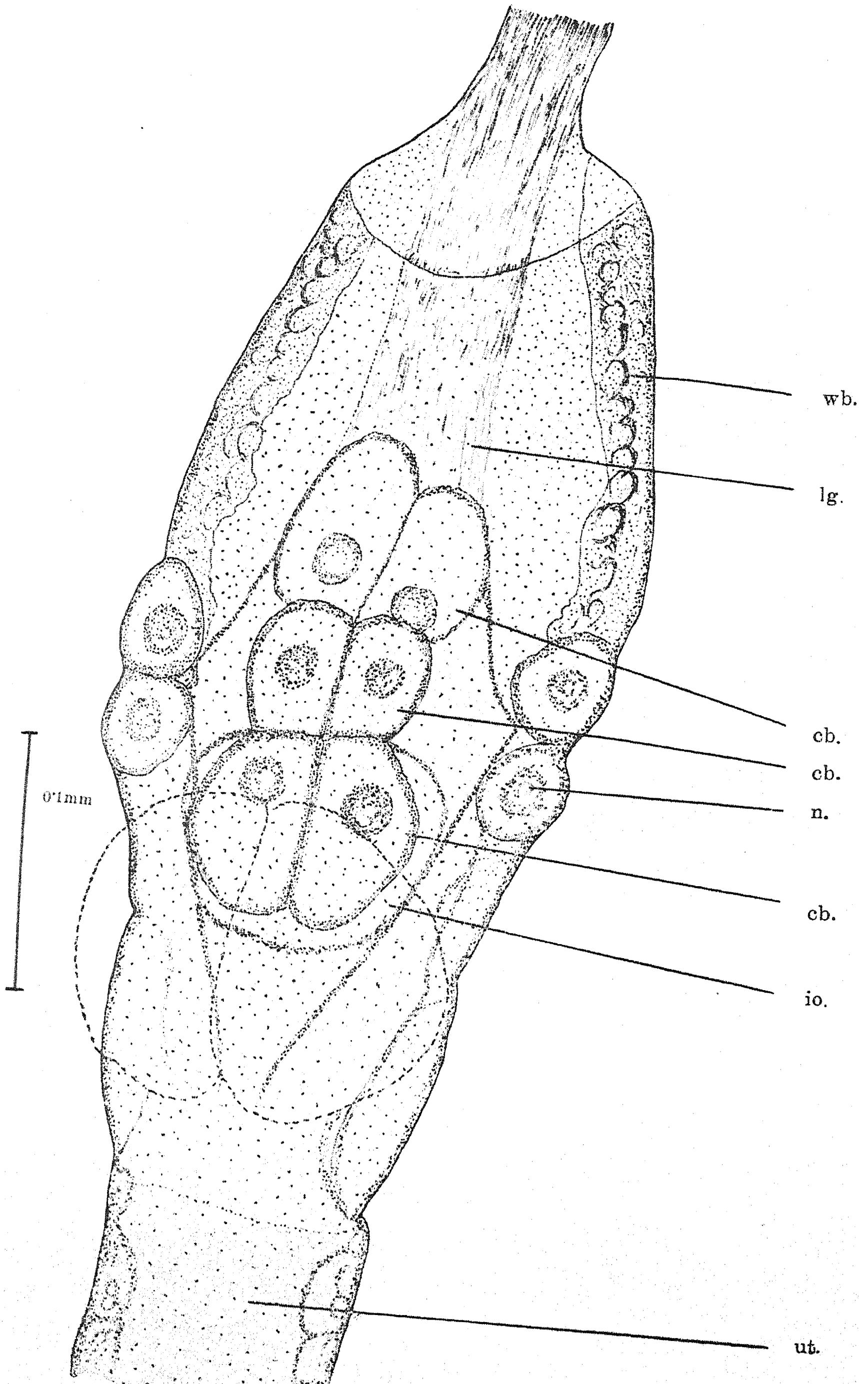
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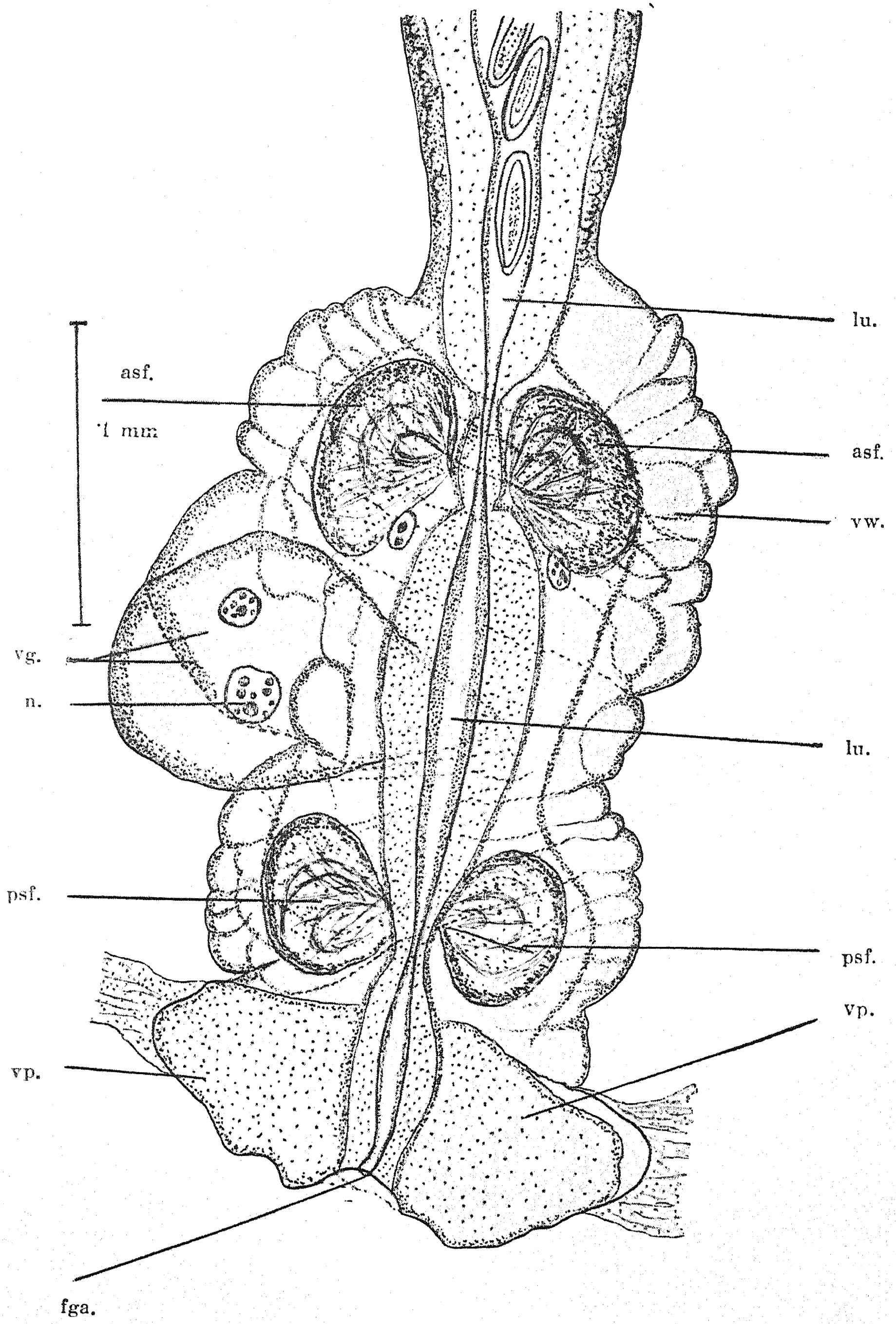
PLATE IX



20. Posterior portion of the female genitalia magnified, showing the vagina, vaginal glands, sphincters, vaginal plates, etc., and spiral muscle fibres of the wall.
21. T. S. through the vagina showing all the parts including a portion of the duct of the vaginal gland.
22. T. S. through one egg mass showing many sections of ova at different stages of development.
23. One complete ovum.

ADDENDUM.

Marval (1902) has described three species of Echinorhynchus, *i.e.*, E. pigmentatus, E. rostratus and E. compressus, from crows (Corvus corone, C. frugilegus, C. cornix and C. monedula), characteristics of which are briefly mentioned in Table 6, but the species described by me as Echinorhynchus sp. inq. differs from them in the following features:—

(1) Size and shape of the body, (2) size and shape of the proboscis, (3) size and shape of the proboscis sheath, (4) number and shape of spines, (5) shape of the basal piece, (6) the number and arrangement of retractor cephaliques, and (7) the presence of vagina with muscular sphincters, as will be seen in the table. These points are of sufficient importance to give it the rank of a new species for which I propose the name *Echinorhynchus robustus*. It, however, resembles closely E. pigmentatus in the size of the body, number of rows of spines and their shape, and presence of canalicular system.

REFERENCE.

Marval, L. (1902)—Etude sur quelques Echinorhynques d' oiseaux. *Arch. parast.* V, pp. 485—489.

Table 6—showing characteristics of the species of **Echinorhynchus** *found in crows (Corvus).*

Species.	Body.	Rostrum or Proboscis.	Proboscis sheath.	Sexual organs.
1. *Echinorhynchus pigmentatus*, Marval (from C. corone), 1902.	Body large and a little flattened. Length without rostrum 10—14 mm. System of vacuoles, in the body wall, always present.	1·9 by 1·4 mm. in size. 30 rows of 15 hooks each. Hooks short and curved at their points; basal piece circular or disc-shaped; length 30—45 μ.	1·4 by 0·4 mm. in size. Composed of two layers of muscle fibres.	The uterus terminates into 2 small swellings of muscles called vagina of 40 μ by 20 μ in size.
2. *E. rostratus*, Marval (from C. corone and C. frugilegus), 1902.	Elongated and elliptical. Length without rostrum 4·2—7·5 mm., breadth 1·9 mm. in the middle and at the extremities 1·2 mm. Symmetrical at both ends.	1·3—1·5 mm. by 0·3 mm. in size 18—20 rows of 18 hooks each. Hooks—proportionately longer as compared with the size of the body; basal piece tubercular; length 60—70 μ.	Remarkably long; 2·3 by 0·2 mm. in size; retractor cephaliques arise from the anterior extremity and terminate on the sides of the penis or vagina. Two more retractors arise further back and separate near the posterior extremity of the sheath joining the retractor cephaliques at the posterior end.	Testes elliptical 0·4 mm. in length; prostates in the form of long tubes measuring 1·9 mm. in length; receptaculum seminis ends in muscular penis.
3. *E. compressus*, Marval (from C. cornix and C. monedula), 1902.	Body oblong. Size 3·8 by 1·2 mm. Richly pigmented.	0·7 by 0·8 mm. in size. Hooks—10 rows of 4-5 hooks each; 200 μ by 50 μ in size.	Oval, 0·8 by 0·3 mm. in size. 2 pairs of retractors are present. One pair arises from the anterior extremity and terminates at the posterior end of the	Sexual organs not described on account of deep coloration of the skin.

			body, while the 2 bands of the other separate at the end of the sheath and terminate a little in front of the posterior extremity.	
4. *E. robustus*. n. sp. (from C. corax and C. splendens).	Body somewhat cylindrical, slightly tapering towards the ends, with annular furrows. Colour olive. Length with proboscis 16—24 mm. and breadth 2—4·5 mm. Females always larger. Canalicular system present in the body-wall.	Oval. 0·48—0·58 by 0·39—0·50 in size. Hooks—28—30 rows of 8—12 hooks each; 30 μ by 15 μ in size; short and curved at the points; basal piece rectangular.	Elongated sac, composed of 2 layers of muscle fibres; 0·93—1·25 mm by 0·32—0·40 mm. in size. About 6—8 muscle bands arise from the posterior extremity of the sheath and run for a short distance ending about the middle of the body.	In the male 2 elliptical testes of 1·25—1·8 mm. by 0·7—1 mm. size. 6 tubular prostates present; seminal vesicle ends in muscular penis; bursa present. In the female the long uterus ends in a thick-walled vagina with muscular sphincters.

TREMATODE PARASITES OF THE PLEUROGENETINAE FROM RANA TIGRINA WITH A REVISION AND SYNOPSIS OF THE SUB-FAMILY

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CONTENTS.

1. Introduction and previous work on the Pleurogenetinae.

Rana tigrina—the common Indian frog is generally found infected in Northern India with *Ganeo tigrinum* n. sp.,

Pleurogenes gastroporus Lühe var. equalis n. var. and *Prosotocus indicus* n. sp., the species of the three different genera which constitute the sub-family Pleurogenetinae. In Southern India this frog is infected with *G. Glottoides var madrasensis* n. var. All the above mentioned species are described in the present paper and as the literature on the subject is scattered and mostly in German, it has been considered desirable to give as far as possible a complete account of the sub-family.

The Pleurogenetinae was established in 1899 by Looss (7) who included in it *Prosotocus confusus Lss*, *Prosotocus tener* Lss, *Pleurogenes medians* Olss, *Pleurogenes Claviger* Rud. Klein (4) in 1905 founded the genus *Ganeo* from *Rana hexadactyla*, a frog from Madras. He was not sure about the position of this genus. Though he included it in the Pleurogenetinae, he considered it to be very different from the other genera of the sub-family. He included the species *Prosotocus confusus* Lss and *Prosotocus tener* Lss under *Pleurogenes* in his key of the species of the genus Pleurogenes (4). Odhner (15) in 1911 constituted a new family Lecithodendriidae and subdivided it into two sub-families Lecithodendriinae and Pleurogenetinae, which he clearly defined. He discussed the position of the genus *Ganeo* and assigned to it definitely a position in the Pleurogenetinae in which he also suggested the inclusion of the genus *Brandesia* Stoss. Nickerson (14) had described in 1900 *Distomum arcanum* from the closed cysts surrounding the pylorus of the common frog found in North America. This species, which was included in a new genus *Loxogenes* by Stafford (21) in 1905 and re-described by Osborn (16) in 1909 Odhner (15) considered to be undoubtedly a Pleurogenetine. Klein (4) in 1905 had included it in his key under the name of *Pleurogenes arcanus*. *Pleurogenes gastroporus* was discovered by Lühe in 1901 from an Indian frog *Rana*

cyanophlyctis. Klein (4) described in 1905 *Pleurogenes sphericus* from R. hexadactyla and Johnston (3) in 1912 *P. freycineti* and *P. solus* from Australian frogs. Ozaki (17) in 1926 described *P. Lobatus* from the bile duct of the Japanese frog *Polypedates buergeri* (Schlegel). *Prosotocus tener* Lss is the only Pleurogenetine which is not found in Anura, but in *Chamaeleo basiliscus.* Scrajabin (18) in 1922 described *Ganeo glottoides var. africana* from one of the African frogs. Bhalerao (1) in 1926 mentioned the existence of *Ganeo glottoides* in *Rana tigrina* at Allahabad, but he gave no description. It is very likely the species described in this paper under the name of *Ganeo tigrinum.*

It was a troublesome question to both Looss and Lühe to decide the systematic position of the Lecithodendriinae and Brachycoeliinae. The resemblance between the genera *Brachycoelium* and *Lecithodendrium* as shown by the well-known species *Br. salamandrae-Distomum crassicolle* Rud was at one time considered to be so great that the latter species was assigned by Lühe to the genus *Lecithodendrium*—a position which was contested by Looss (9) and which consequently turned the Lecithodendriinae into disfavour so much so that all the genera belonging to it were assigned to the sub-family Brachycoeliinae Lss. Lühe (11) adopted this latter course in the Susswasserfauna Deutschlands. Odhner (15) in 1911 removed all the genera except *Brachycoelium* from the Brachycoeliinae and included them in the sub-family Lecithodendriinae, which then is the Brachycoeliinae Lss minus *Brachycoelium.* The latter genus comprising the Brachycoeliinae was assigned by him to the family Dicrocoelidae. Cort (2) and we (12) found this position untenable and assigned it to the family Lepodermatidae (Plagiorchiidae). Odhner's view about the relationships of the sub-families Lecithodendriinae and Pleurogenetinae appears acceptable in view of the fact that the genus

Ganeo like *Lecithodendrium* and *Pycnoporus* lacks the true cirrus sac. In *Ganeo glottoides* as well as in its varieties a pseudocirrus sac is present, while in *Ganeo tigrinum* even this is absent. The shape of the excretory bladder is also similar in the two sub-families. But a further knowledge of the Lecithodendriinae is necessary before we can give our final opinion about this question.

We offer our sincerest thanks to Professor Ram Muni Menon for sending us the live specimens of *Rana tigrina* from Madras, which furnished us with a fairly good number of *Ganeo glottoides var madrasensis* and to Major R. B. Seymour Sewell who always put ungrudgingly the library facilities of the Indian Museum at our disposal at Allahabad.

2. Ganeo tigrinum n. sp.

Ganeo tigrinum was found in the posterior three-fourth part of the small intestine and rectum of *Rana tigrina*. Out of eighty-nine specimens examined, nineteen harboured this parasite; it appears therefore that nearly one out of every five frogs is infected with it, and that next to *Tremiorchis ranarum* Mehra and Negi syn *Centrovitus pentadelphi Bhal*erao (1) it is the commonest Trematode found in this frog. The number of parasites in a host is variable; five frogs were found infected with 1, 2, 9, 23 and 50 specimens respectively. The distomes are attached to the wall of the intestine by the ventral sucker and do not get easily detached when the intestine is opened. When put in a watch-glass in water or salt solution they float about raising the anterior and contracting other portions of the body. In the intestine of the host they have been observed to move by their suckers and spines. The body has a great power of extension and contraction. Various methods were tried to keep them alive outside the body of the host in nutritive solutions as will be seen from Table I. Five specimens lived for 264 hours and four for 125 hours. This species is less

susceptible to varying conditions of diet and temperature and is better able to adapt itself to changed conditions than *Tremiorchis ranarum*. In summer they could not survive in similar solutions for more than 52 hours. The Trematode measures 2·5—5·7 mm. in length when alive. The smallest sexually mature individual contained a large number of eggs in the coils of its uterus. The detailed measurements of the length and breadth of living specimens are given in Table II.

TABLE I.

Mid-winter (December and January): temperature of Lab 65°—70° F.

Nutritive solutions used.	Normal salt solution.	5% Sugar solution.	Egg albumen.	Mix. of 4 c.c. egg albumen and 2 c.c. normal salt solution.	Yolk of egg.	Mix. of yolk and normal salt solution 2 : 1.	Mix. of egg albumen, yolk and normal salt sol. 2 : 2 : 1.
No. of Trematodes kept.	4	4	4	7	3	6	4
No. of hours Trematodes lived.	36	36	24. One for 125 hours.	36. Five for 264 hours.	48	48	125

In entire mounts the length measured 2·4—3·7 mm. and the breadth ·96—1·63 mm. at the level of the posterior end of the vitellaria, 1·14—1·37 at that of their anterior end and ·72—·99 mm. at that of the genital opening. The above measurements show a great range of variability in their size. The colour is grey. The body gradually increases in breadth from the anterior to the posterior extremity and is broader near the latter than in any other part; its anterior extremity is bluntly pointed and the posterior has a somewhat rounded outline. The surface of the body is completely covered with small spines of a triangular shape closely set in irregular rows. The spines are more numerous around

the oral sucker where they are also somewhat larger in size; their distal end is pointed unlike that of the spines of *G. glottoides.* In the latter species they are mainly present in the anterior part of the body; their number becomes much smaller behind the ventral sucker and they are completely absent behind the end of the intestinal caeca. The suckers are nearly spherical in outline. The ventral sucker is distinctly larger than the oral and bears to it a ratio of : 3 2 as will be seen from Table III.

TABLE II.

Living Specimens.

Length of individual.	Width of the region containing ventral sucker.	Width of the region in which intestinal caeca end.
2·59	1·02	·99
3·1	1·1	1·05
3·3	1·5	1·2
5·7	1·8	1·8
3·6	1·7	1·8

Klein (4) does not give any description nor measurements of the suckers in *G. glottoides*; but from his figures it appears that the oral sucker is larger than the ventral sucker—a condition quite reverse of that in our species. The oral sucker occupies a subterminal position on the ventral surface and is surrounded by spines which are somewhat larger than those elsewhere. The ventral sucker lies at about one-third distance from the anterior end as the measurements given in Table IV will show.

TABLE III.

Diameter of oral sucker.	Diameter of ventral sucker.
·12	·18
·13	·18
·19	·27
·24	·33
·18	·27

TABLE IV.

Length in front of ventral sucker.	Length behind ventral sucker.
1·005	2·13
1·5	2·1
1·9	3·5
1·1	2·3
1·3	3·1

The genital opening lies on the ventral surface near the left side margin of the body at about ·6—·9 mm. distance from the anterior end as examined in living specimens. It is situated at about the level of the middle of the oesophagus or its commencement nearer the intestinal bifurcation than the oral sucker. Its position varies within narrow limits from individual to individual and nearly corresponds to that given for *G. glottoides* Klein. The excretory opening lies on the ventral surface a little distance in front of the posterior end of the body.

The mouth lies at the bottom of the subterminal oral sucker and opens into a small thin-walled prepharynx of ·06—·08 mm. length, which is followed by a thick-walled globular pharynx measuring ·07—·12 mm. in diameter, *i.e.*, about half the diameter of the oral sucker. The oesophagus is a narrow tube of ·36—·6 mm. length ; it is moderately long and runs

in the middle line between the oral and ventral suckers. It bifurcates into two intestinal caeca in front of the testes and much in front of the ventral sucker. The intestinal caeca extend a little distance beyond the vitellaria occupying $\frac{4}{5}$th part of body in fully mature specimens and about $\frac{5}{6}$th in individuals which are less mature. They are swollen at the posterior extremity ; but they do not, however, broaden gradually. Each caecum lies in the centre between the margin and the middle line of the body. The right one is a little longer than the left, but the difference is by no means so pronounced as in *G. glottoides* Klein or in *G. glottoides var. madrasensis.*

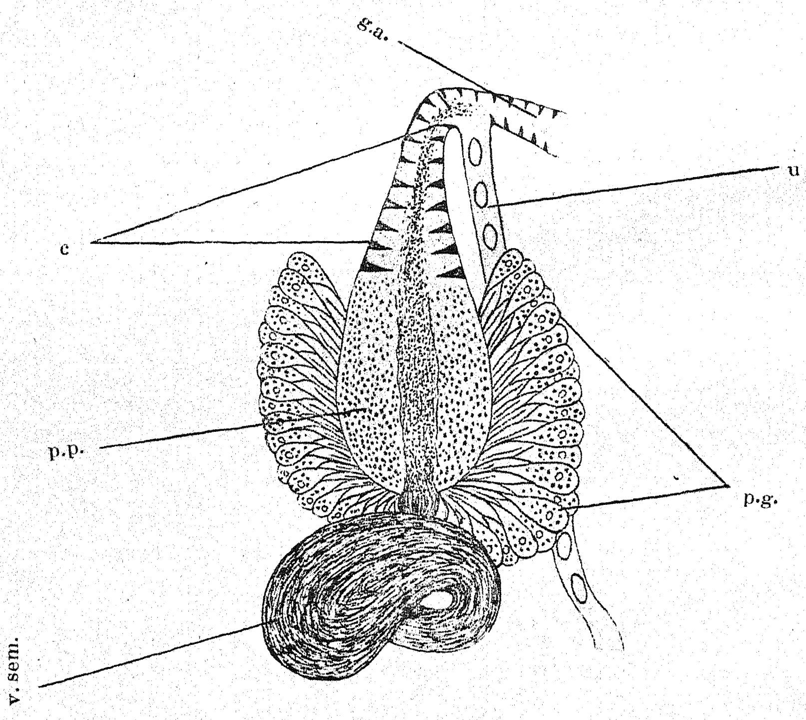
In *G. glottoides var. africana* Scrjabin both the caeca reach near the hinder end of the body. Scrjabin remarks : "In comparing the African parasite with the Indian it is first of all noticeable that the intestinal trunks in the former nearly reach the hinder end of the body, whereas in the latter the blind extremities of the intestine are far from the end of the body (see Fig. 6 in Klein's work). However, this character is of no specific value as in several specimens of *G. glottoides* Klein observed a different length of the intestinal trunk." It may be pointed out that Klein never found both of them reaching near the posterior end of the body.

The reproductive organs except the vitellaria and the coils of the uterus lie in the anterior half of the body. The testes and the ovary are situated near one another but not apposed to each other as in *G. glottoides* Klein ; on the other hand, they are quite separated and can be easily distinguished whether in living or preserved specimens. Both the testes lie obliquely behind each other in the anterior one-third body in front of the ventral sucker and are nearly spherical in outline. The anterior testis is situated immediately behind the intestinal bifurcation in the space between intestinal caeca, while the posterior lies in front of ventral sucker or sometimes at the same level with it close to the

right intestinal caecum and covers it sometimes partly on the dorsal side. The anterior testis of 0·21—0·03 mm. diameter is smaller than the posterior testis which has 0·27—0·36 mm. diameter. In the position of the gonads this species comes near *G. glottoides* Klein, the only noticeable difference being their separation from one another. In *G. glottoides var. africana* their position is shifted backwards so that the anterior testis occupies the position of the posterior testis of *G. glottoides* Klein, and the posterior testis has been pushed behind the ventral sucker occupying the position of the ovary of the latter, while the ovary is shifted towards the left side behind the ventral sucker. In *G. glottoides var. madrasensis* all the gonads have been shifted further back to a position behind the ventral sucker and the testes are so displaced that instead of lying one behind the other they lie one on each side. The difference in the position of the gonads though quite striking in the two varieties should not be considered as specific in view of the fact that this species shows a remarkable range of variation in the topography of these organs.

The vesicula seminalis has more or less the same appearance, *i.e.*, the form of a coiled bladder as in *G. glottoides* Klein, but the long narrow tube into which it continues before it opens into the pars prostatica is absent in our species. Its form depends greatly on its dimensions due to the measure of its contents and the conditions of preservation, but it has almost always the form of a U-shaped loop filled with sperms. Its narrow distal part before it opens into the pars prostatica is somewhat swollen and has a rounded outline. The pars prostatica is a large, elongated pear-shaped chamber having nearly the same shape as in *G. glottoides*. It is 0·32 mm. in length and 0·1 mm. in maximum breadth and gradually becomes narrow towards the distal end to form a cirrus, which appears sharply separated from it. The epithelium lining the seminal vesicle consists

of very thin flat cells which are covered outside by a thin layer of longitudinal muscle fibres. The cells lining the pars prostatica are always enlarged inwards owing to the inward flow of the prostatic secretion through them and consequently encroach a good deal upon the lumen. The cells of the opposite walls become so expanded by the accumulated secretion within them that they come near each other filling a great portion of the lumen of the duct. In extreme cases of maturity the cells degenerate, break down and become more or less completely replaced by the secretion passing through them into the lumen. Such relation of the prostate cells with the pars-prostatica has been described

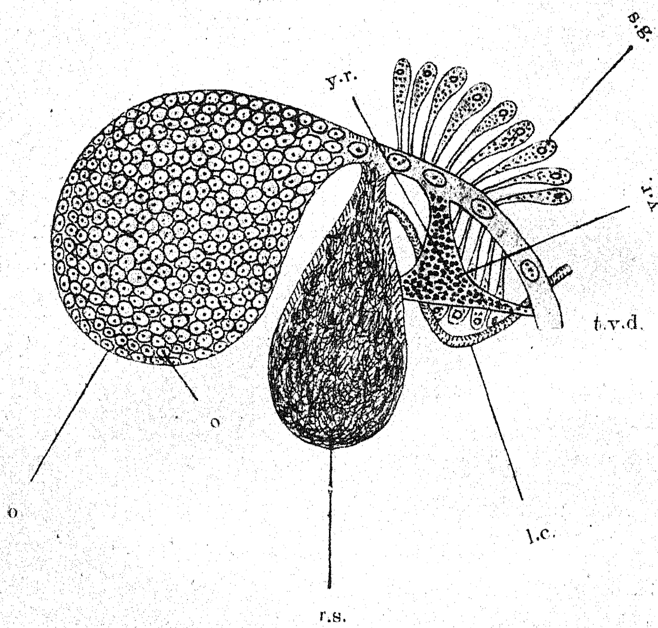


TEXT FIGURE 1 :—VAS EFFERENT APPARATUS OF G. TIGRINUM.
c., cirrus; g.a., genital atrium, p.g., prostate gland cells; p.p., pars prostatica; v. sem., vesicula seminalis; u., terminal part of uterus.

before (12), and we believe that it is of universal occurrence in the Trematoda, where the prostate gland cells exist. It is remarkable that it resembles closely that of the prostate cells and the atrium in the Microdrili. The epithelium is surrounded by a thin layer of longitudinal muscle fibres, which is continuous with that of the cirrus to be descried later. The prostate gland cells, which appear somewhat dark in living specimens are large and conical; they lie in enormous numbers around the pars-prostatica, in whose walls they pour their secretion by long narrow ductules. Their broad outer ends contain a granular basophile cytoplasm and a nucleus. The cytoplasm in the ductules of the prostatic cells, as well as that in the epithelial cells of the pars-prostatica into which the former discharge their secretion is acidophile in reaction. The cirrus sac or pseudocirrus sac is absent and the prostate cells lie freely in the parenchyma outside the pars-prostatica. Their position and appearance show that they are parenchymatous in origin representing the replaced parenchyma of this region. The male efferent apparatus is not enclosed here by a membranous parenchymatous sheath—the pseudocirrus sac which is a characteristic feature *of G. glottoides* Klein and *G. glottoides var. madrasensis.* The cirrus is a thick-walled tube 0·075—0·15 mm. in length, *i.e.*, about half the length of the pars-prostatica and 0·051 mm. in greatest breadth. It is sometimes swollen at the base, *i.e.*, the part adjacent to the pars-prostatica but otherwise it is a narrow tube of a more or less uniform breadth. Its wall is composed of a layer of longitudinal muscle fibres from which there project inwards a number of spines in regular rows. The lining epithelium is absent. The spines are pointed at the inner end and lie freely in the lumen attached at their base to the muscular wall of the cirrus. They are 0·013—0·017 mm. in length and are larger in the basal than in the terminal part. The

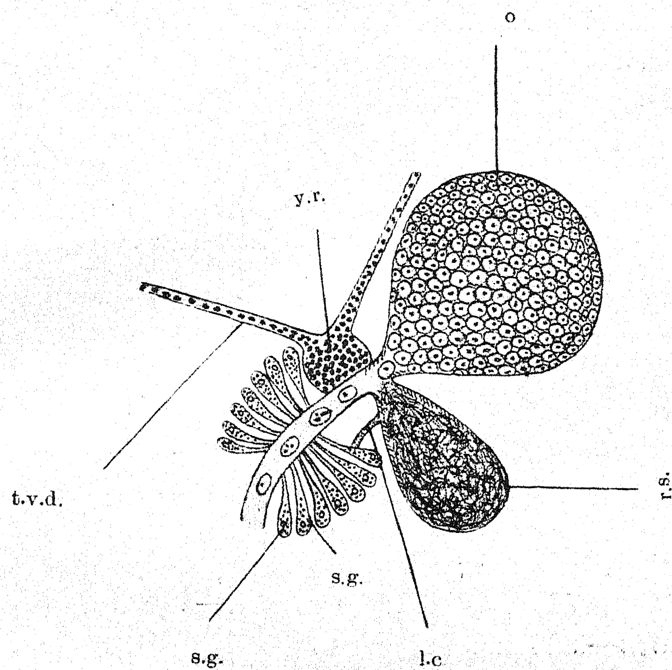
cirrus opens into the genital atrium—a deep depression of the body wall lined with a chitinous layer, which is continuous outside with that of the body wall through the genital pore. The genital atrium is 0·01—0·15 mm. in length (depth) and 0·045—0·075 mm. in breadth; it lies on the ventral side near the left border of the body extending inwards from the genital opening in an obliquely upward direction. The cirrus opens into it ventrally at the inner end, while the

A

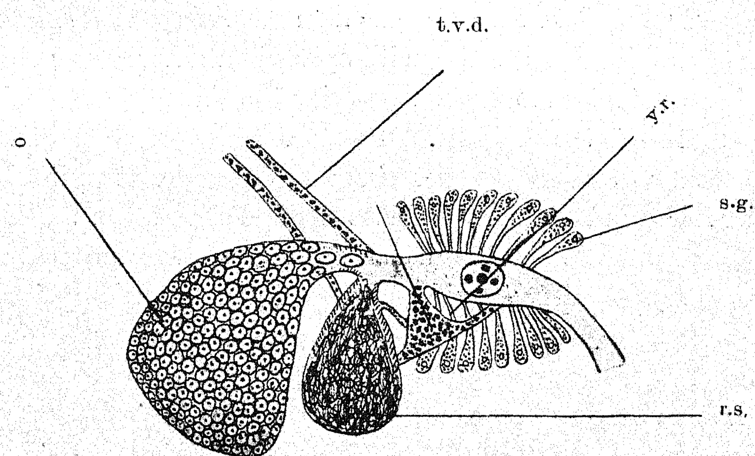


TEXT FIG. 2. A—C :—DIAGRAMMATIC VIEW OF FEMALE GENITAL ORGANS OF A., G. TIGRINUM ; B., PL. GASTROPORUS VAR. EQUALIS AND C., PR. INDICUS. o., ovary; l.c., Laurer's canal; r.s., receptaculum seminis; s.g., shell gland; t.v.d., transverse vitelline duct; y.r., yolk reservoir.

B



C



uterus opens on the left side in front of it. The chitinous layer is beset closely with small spines. A layer of longitudinal muscle fibres continuous with that of the body wall surrounds it outside.

The ovary is somewhat pear-shaped or rounded in outline and is 0·18—0·32 mm. in diameter, *i.e.*, about four-fifth diameter of the anterior testis. It is situated behind the ventral sucker and the posterior testis to the right side. The relations of the female ducts are shown in text-fig. 2. The oviduct arises from the inner margin of the ovary and receives at once the duct of the receptaculum seminis. The latter is a flask-shaped structure placed closely behind the ventral sucker at the level of the anterior border of the vitellaria with its long axis parallel to the length of the body. It varies considerably in size (0·18 mm.—0·39 mm. in length and 0·075—0·24 mm. in greatest breadth) ; it may be sometimes though rarely larger than the ovary. Its duct which receives the Laurer's canal is a little broader than the latter. The Laurer's canal is a narrow tube which runs forwards to open on the dorsal surface of the body in front of the ovary. Both the receptaculum seminis and Laurer's canal are lined as usual with epithelium having long cilia, which constantly move outwards in the direction opposite to that of the oviduct. The oviduct further receives the common vitelline duct from the prominent vitelline reservoir and then continues behind as uterus. The shell gland cells of the usual form surround the ootype, *i.e.*, the part of the oviduct between the opening of the receptaculum seminis and the commencement of the uterus. The convolutions of the uterus occupy the space between the intestinal caeca in the posterior half of the body. They are so closely crowded that it is difficult to follow

their course, but they lie in a transverse direction having nearly the same arrangement as in *Ganeo glottoides* Klein. The windings of the descending part occupy a dorsal position, while those of the ascending part lie ventrally. It is, however, difficult to distinguish them where they form a compact mass specially near the intestinal caeca. The convolutions are not so compact near the posterior end of the body as in front; moreover here they are proportionately small and lie side by side in close contact with one another. The outgoing part of the uterus passes ventrally to the receptaculum seminis and to the left side of the ventral sucker in front continuing a more or less straight course till it passes along the vesicula seminalis and cirrus sac to open into the genital atrium.

The ova are long oval or elliptical in shape and rounded at both ends measuring 0·3 by 0·015 mm. in size. Their colour when ripe is dark brown.

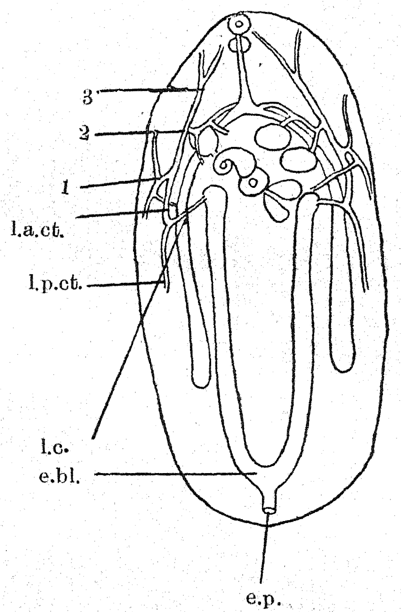
The vitellaria lie mostly on the ventral surface of the intestinal caeca; they also surround the latter on the sides as in *G. glottoides* Klein. Their position on the ventral side of the body in contrast to the usual dorsal position in other distomes is a characteristic feature of this genus. They extend from the posterior border of the ovary to approximately half the distance between the ventral sucker and the posterior end of the body and always terminate in front of the blind end of the caeca. The follicles are closely crowded together showing a regular arrangement with a characteristic appearance. They are oval, pear-shaped or occasionally rounded and measure 0·044—0·068 mm. in maximum diameter. They do not, however, appear to be arranged in groups. The anterior and posterior vitelline ducts join near the middle of the body to form the transverse ducts which

run obliquely towards the centre. The vitelline reservoir is fairly large.

It is difficult to study the excretory canals properly in entire mounts or live specimens on account of the presence of numerous large gland cells, which are densely crowded in the parenchyma in the anterior half of the body near the side walls. In the posterior half of the body the same difficulty is presented by the enormous number of ova. The canals were, however, seen in the anterior half of the body in young specimens both mounted and alive. The excretory pore lies on the ventral surface near the posterior end of the body but it is not terminal. It leads into a very small rather rudimentary median stem of a U-shaped bladder. The two limbs or horns of the bladder extend as far forwards as the ventral sucker occupying about two-thirds of the length of the body. Their anterior ends are slightly swollen. Each limb receives a common collecting tube, which runs outwards almost transversely and receives the anterior and posterior collecting tubes at about the level of the receptaculum seminis. The distribution of these tubes is shown in text-fig. 3. Each of the collecting tubes receives three accessory collecting tubes, each of which is supplied by three capillaries except the anteriormost one which receives only two capillaries. The position and arrangement of the capillaries can be seen from the figure. In each capillary group the accessory collecting tube divides into two branches, one of which runs directly as the capillary itself and the other divides further into two capillaries. The paired capillaries go to one side and the unpaired one to the other. The flame cells were not observed. It is expected that the posterior accessory collecting tubes and their capillaries would correspond in their arrangement and distribution to those of the anterior part of the excre-

tory system. It appears that formula for the excretory system is the same as in *Pleurogenes claviger* (5), *Margeana californiensis* (2) and *Tremiorchis ranarum* (12), *i.e.*, " $2 \times 6 \times 3$ " = 36.

REMARKS:—*Ganeo tigrinum* resembles closely *Ganeo glottoides* Klein. The resemblance is striking specially in



TEXT FIG. 3:—EXCRETORY SYSTEM OF G. TIGRINUM.

e. bl., excretory bladder; e.p., excretory pore; l.c., common collecting tube; l.a.ct., left anterior collecting tube; l.p.ct., left posterior collecting tube; 1, 2, 3, three accessory collecting tubes.

such minute characters as the size of the body, position of the ventral sucker, length and breadth of the pharynx, oesophagus and intestinal caeca, position of the gonads, size of the ovary and ova, arrangement of windings of the uterus, position of the vitellaria and form of the excretory bladder. But the important points of difference are as follows:—

Shape of spines. They are elongated and pointed in *G. tigrinum*, while in *G. glottoides* they are scale-like.

(2) Ratio in the size of oral and ventral suckers is 9 : 8 in *G. glottoides*, 7 : 6 or 6 : 5 in *G. glottoides var. madrasensis*, 1 : 1 in *G. glottoides var. africana* and 2 : 3 in *G. tigrinum.*

(3) Absence of pseudocirrus sac.

(4) Absence of long narrow duct of vesicula seminalis.

(5) Excretory pore is subterminal and ventral in our species.

(6) Intestinal caeca are nearly of the same size.

3. Ganeo glottoides var. madrasensis, n. var.

The species was obtained from the small intestine of *Rana tigrina* sent from Madras by Prof. Ram Muni Menon. Twenty-two specimens were collected from one frog, two from the other and one from the third. They were thin and transparent so that by a slight pressure of the cover glass the internal anatomy could be easily seen under a low power. The body is flat, somewhat conical, more pointed at the anterior than at the posterior end which is somewhat rounded. It is broadest in the region containing the ventral sucker and gonads and gradually tapers behind till it becomes much narrow near the ends of the intestinal caeca. It becomes narrow also anteriorly in front of the genital opening. The size varies from 1·64—4 mm. in length and 0·74—0·98 mm. in breadth at the level of the ventral sucker, and 0·62—0·84 mm.

at that of the blind end of the left intestinal caecum. In young specimens of about 1·65 mm. length in which the uterus is not developed the breadth at the level of the ventral sucker is 0·64—0·66 mm. and at that of the end of the left intestinal caecum 0·42—0·53 mm. The part of the body in front of the ventral sucker is covered by very small spines, which are only visible under the high power. They gradually decrease in number behind the genital opening till they completely disappear at about the level of the ventral sucker.

The oral and ventral suckers are nearly spherical in outline. The ventral sucker lies at about ¼th length of the body from the anterior end or at about half the distance between the oral sucker and the ovary. Its walls are less strong than those of the oral sucker. The comparative diameters of the two suckers as seen in entire mounts are as follows :—

Diameter of oral sucker	Diameter of ventral sucker
0·15	0·14
0·13	0·12
0·12	0·1
0·13	0·1

These measurements show that the ratio in their size is about 7 : 6 or 6 : 5.

The prepharynx is very small and opens into a pharynx of 0·9 mm. diameter. The oesophagus is small measuring 0·14—0·21 mm. in length. The intestinal bifurcation lies just in front of or at about the level of the genital opening. The right intestinal caecum is always longer than the left one and reaches about $\frac{1}{3}$ mm. distance in front of the posterior end of the body. The left intestinal caecum occupies about three-fourth length of the body. Klein (4) found this difference in the length of the caeca in most of his specimens, but in the present variety it is seen in every individual whether mature or not.

The testes lie obliquely one on each side behind the ventral sucker in the posterior region of the anterior third of the body; the left testis occupies generally a slightly anterior position. They are not placed one behind the other as in *G. glottoides* or *G. tigrinum*; on the other hand they lie one on each side though not exactly at the same level. The position of the testes here shows probably a reversion to the primitive condition bringing the genus *Ganeo* nearer *Prosotocus*, *Pleurogenes* and *Brandesia.* It is remarkable that the position of the gonads varies so profoundly even in different varieties of this genus. The left testis is situated close behind the ventral sucker near the median plane separated from the left intestinal caecum by a small distance. It is sub-spherical or slightly ovoid and measures 0·18–0·32 mm. in diameter. The right testis lies to the right side of the ventral sucker near or more often a little behind the left testis covering ventrally a great part of the right intestinal caecum. It is somewhat ovoid and slightly larger than the left testis measuring 0·196—0·26 mm. in length and 0·21 mm. in breadth. The relation of the testes to each other and to the other genital organs remains the same throughout life. The pseudocirrus sac is long and slightly curved consisting of a small vertical basal portion and a long transverse portion. It lies in front of the testes

behind the intestinal bifurcation with its basal portion to the right side of the ventral sucker. The transverse portion runs dorsally to the left intestinal caecum and becomes slightly curved before it opens into the genital atrium. The shape and position of the pseudocirrus sac differs from that of *G. glottoides* Klein and *G. glottoides var. africana* Scrajabin, though there is no difference in its structure, which is nothing more than a parenchymatous sheath around the vas efferent apparatus. The vesicula seminalis twisted as usual occupies the basal portion of the pseudocirrus sac. It is followed by a long pars-prostatica surrounded by small prostate gland cells. The genital atrium is shallow and eversible. The genital opening lies close behind or at the level of the intestinal bifurcation on the ventral surface near the left border of the body. The ovary is spherical in shape situated behind the right testis near the median line and is 0·16 mm. in diameter, *i.e.*, nearly half the size of the testis. The receptaculum seminis of 0·05 by 0·088 mm. size lies to the right side behind the ovary near the median line. The shell gland occupies a position inwards to the receptaculum seminis about the centre of the body. The uterus convolutions follow very much the same course as in the other species. The terminal part of the uterus as it passes between the two testes lies near the left one, which it crosses dorsally to the left side of the ventral sucker to continue its outward course. Before it opens into the genital atrium it runs ventrally to the cirrus sac. The ova are elliptical and have 0·027—0·03 mm. size.

The vitellaria lie mostly on the ventral surface and sides of the intestinal caeca, in the middle third part of the body extending from the anterior or posterior border of the ovary to about half the distance between it and the posterior end of the body and terminating a little distance in front of the blind end of the left intestinal caecum. The follicles

are somewhat pear-shaped or oval. They are thickly crowded and their number is generally smaller in the left vitellarium. The transverse ducts arise anteriorly, *i.e.*, at about one-third length of the vitellaria from the anterior end and join behind the ovary to form the conspicuous reservoir.

The excretory opening is terminal and lies at the posterior end of the body. The shape of the excretory bladder is similar to that of the type species. The important features which distinguish this variety from *G. glottoides* Klein are the small size of the oesophagus, constant difference in the length of the two intestinal caeca, position of the testes one on each side of the body, position and the strongly curved form of the pseudocirrus sac.

Remarks :—The genus includes *G. glottoides* Klein, *G. glottoides var. africana* Scrajabin, *G. glottoides var. madrasensis,* and *G. tigrinum* n. sp. The resemblance in the above-mentioned forms is, however, striking in such minute characters as the size of the body, length and breadth of pharynx and oesophagus except in *G. glottoides var. madrasensis*, position of genital pore, size of ovary and ova as will be seen in Table VII. *G. glottoides var. africana* in our opinion deserves the rank of a species. The length of the intestinal caeca which reach near the posterior end of the body, position of the gonads and the vitellaria, appear to be features prominent enough as to deserve a specific rank. In *G. glottoides* Klein the gonads are closely apposed to one another, in *G. tigrinum* they are separated so that the ovary comes to lie entirely behind the ventral sucker ; in *G. glottoides var. africana* they are pushed further backwards, so that the anterior testis occupies the position of the posterior testis of *G. glottoides* Klein, and the posterior testis that of the ovary of the latter, while the ovary lies behind the ventral sucker to the left side. In *G. glottoides var. madrasensis* both the testes and the ovary lie behind

the ventral sucker. It appears that the backward movement of the testes resulting in the position of the ovary behind the ventral sucker to the left side in *G. glottoides var. africana* is a last step in the sequence of events in which *G. tigrinum* shows an intermediate condition. The vitellaria in this variety end much in front of the termination of the intestinal caeca.

The systematic position of the genus has been discussed by Klein (4) and Odhner (15). We also maintain that it belongs to the sub-family Pleurogenetinae. Though the topography of the gonads varies remarkably as mentioned above in the different varieties of a species, position of the testes, one on each side of the body in *G. glottoides* var. *madrasensis* shows probably a case of reversion to the primitive condition which is met with in the genus *Pleurogenes.* It seems that the position of the testes in other species of *Ganeo* is aberrant for the sub-family. The Pleurogenetine characters of the genus *Ganeo* are the following:—genital opening near the left border in the anterior part of the body, ovary near the ventral sucker to the right side or near the median line, twisted vesicula seminalis, well-developed pars-prostatica and prostate gland cells, presence of male efferent apparatus in the anterior part of the body, position of testes in *G. glottoides var. madrasensis*, arrangement of the uterus convolutions, U-shaped excretory bladder with a rudimentary median stem which can be easily derived from a V-shaped condition and "2×6×3" excretory system. The absence of a true muscular cirrus sac, position of the vitellaria, shape of the excretory bladder and absence of a terminal muscular part of the uterus, *i.e.*, metraterm are the important differences.

The affinities of the Pleurogenetinae with the Lecithodendriinae were recognised by Odhner (15), who included these two sub-families in the family Lecithodendriidae. They

are based on the presence of a V-shaped excretory bladder, position of the ventral sucker in the middle of the body, situation of the ovary near it to the right side or about the median plane, presence of a receptaculum seminis and a small Laurer's canal, vitellaria in front of the middle of the body and disposition of the convolutions of the uterus. Though *Ganeo* differs much more from the Lecithodendriinae than the Pleurogenetinae, the absence of cirrus sac brings it closer to such genera of the former as *Lecithodendrium* and *Pycnoporus*. Though the anatomy of this genus is aberrant from that of the Pleurogenetinae, there appears to be no doubt that it belongs to this sub-family.

4. PLEUROGENES GASTROPORUS LÜHE VAR. EQUALIS., N. VAR.

This species was obtained by Lühe in 1901 (10) who had before him only two specimens. We obtained specimens from four out of eighty-nine frogs of *Rana tigrina* dissected at Benares and Allahabad. The number of parasites found in a host was not large being 2, 3, 4, or 10. The distomes get easily detached when the duodenum is opened. They are when alive, 1·5—2·38 mm. in length and about 1 mm. in maximum breadth. In permanent mounts the length varies from 1·12—1·72 mm. The body has a more or less conical form; it is pointed at the anterior and broadest at the posterior end. It has not got much power of extension and contraction. The colour is white grey; the cuticle of the entire body is closely covered with small pointed backwardly directed spines of a triangular shape, which are slightly curved near the free end. They are 0·003 mm. broad at the base and have the same arrangement as described in other species. The oral and ventral suckers are spherical and equal in size. In the description given by Lühe (10) the oral sucker (diameter 0·285 mm.) is smaller than the ventral sucker (diameter 0·315 mm.).

Diameter of oral sucker.	Diameter of ventral sucker.
0·21	0·21
0·18	0·18
0·16	0·16
0·18	0·18
0·18	0·18

The oral sucker is subterminal lying near the anterior end of the body on the ventral surface. The ventral sucker is situated for the greater part of its diameter in the anterior half of the body as the following measurements will indicate :—

Length in front of ventral sucker.	Length behind ventral sucker.
0·37	0·51
0·61	0·73
0·49	0·64
0·52	0·67
0·43	0·69

The pharynx is rounded and 0·1—0·15 mm. in diameter. It is followed by a very small rather inconspicuous oesophagus which divides into intestinal caeca just behind it. The intestinal caeca are small and terminate near the anterior margin of the testes on each side of the ventral sucker. The reproductive organs except the coils of the uterus and a major portion of the testes occupy the anterior half of the body. The testes are spherical and situated symmetrically one on each side about the middle of the body behind the intestinal caeca. They are almost equal in size and have ·19—·24 mm. diameter. The cirrus sac is pear-shaped and large with thick muscular walls; it is 0·35—0·58 mm. in length, *i.e.*, about one-fifth to one-fourth length of the body. Its greatest breadth is 0·14 mm. It lies obliquely to the left side with its long axis parallel to the body length and is slightly curved

in its narrow tubular part like the lettter S. The vesicula seminalis is twisted and occupies the basal portion of the cirrus sac. The pars-prostatica is small; the cells lining it are enlarged on account of the accumulated prostatic secretion as in the species above described. The cirrus has thick muscular walls and opens into a small eversible genital atrium, which becomes easily protruded on the application of a small pressure or during fixation as a small papilla containing within it the terminal part of the cirrus.

The ovary is globular in shape and measures 0·12—0·16 mm. in diameter, *i.e.,* almost half the diameter of the testis. It is situated obliquely in front of the ventral sucker and the testes to the right side of the body. The oviduct arises from its inner margin near posterior end. It runs only for a short distance when it is joined by the receptaculum seminis. The Laurer's canal arises from the latter as in other species of the Pleurogenetinae. The receptaculum seminis and shell gland lie dorsally close in front of the ventral sucker to the right side, where the oviduct receives the common vitelline duct from the vitelline reservoir. The uterus forms a convoluted mass filling the posterior half of the body. Its convolutions are arranged in the form of two longitudinal loops joined by a cross loop, which may be produced behind sometime into a small longitudinal loop, so that there is left a free space in the centre, in which near the hinder end the excretory opening lies. The arrangement of the uterus convolutions appears to be nearly the same as in *Pleurogenes medians.* The terminal portion passes to the left side of the ventral sucker to continue its outward course where it lies parallel to the cirrus sac. The eggs are elliptical and measure 0·02—0·023 mm. by 0·011—0·012 mm. in size. The mature eggs have a deep brown shell. The vitellaria are composed of fairly large follicles, which vary in size and have oval, pear-shaped, somewhat rounded or irregular form. They lie dorsally between the

pharynx and the ends of the intestinal caeca mainly covering the latter; a certain number of them also occupy the region between the intestinal bifurcation and the ovary. The transverse ducts are very small. The vitelline reservoir lies in front of the ovary.

The excretory bladder is U-shaped with a small central stem opening to the exterior. The limbs of the bladder reach as far as the posterior end of the testes. The excretory opening lies a little in front of the posterior end of the body on the ventral surface. Lühe, however, gives its position much in front of the hinder end.

Remarks:—The distomes no doubt belong to *Pleurogenes gastroporus* described by Lühe in 1901 from *Rana cyanophlyctis*. As will be seen from the synopsis of the species of the genus *Pleurogenes* in Table VI our specimens agree closely with Lühe's description, but they differ in the following important features: (1) Position of the excretory pore, which does not lie much in front of the posterior end as in Lühe's specimens. (2) Receptaculum seminis and shell gland lie to the right side in front of the ventral sucker and not in the centre. (3) Equal size of the oral and ventral suckers. In Lühe's specimens the proportion in their size is 28 : 31. The minor differences are (4) size of suckers, (5) small size of the ovary and testes in our specimens, (6) curvature of the cirrus sac not so strongly marked as in the type species and (7) hosts belonging to different species of *Rana*. These points appear to be sufficiently important as to justify the creation of a new variety for which we propose the name *Pleurogenes gastroporus* Lühe var. *equalis*.

5. Prosotocus indicus n. sp.

This species was obtained from the duodenum and small intestine of only eight out of eighty-one specimens of *Rana tigrina*. It appears to be nearly as rare as *Pleurogenes gastroporus* var. *equalis*. The number of parasites as

obtained from five frogs was 1, 3, 5, 12 and 110. They do not get easily detached when the intestine is opened. When kept in water or salt solution on a slide they move about by stretching their extremely mobile anterior end and drawing the part behind it forward; the body also shows a great power of expansion and contraction. The size is small measuring 0·6—1·1 mm. in length in entire mounts and 1·2—2·4 mm. in live specimens. The breadth in entire mounts varies from 0·42—0·45 mm. They have a white transparent body with a rounded outline; when flattened by the pressure of a cover glass, they assume an elliptical form. The cuticle is entirely covered with small narrow backwardly directed spines of the usual shape, which measure 0·007 mm. in length aud 0·001 mm. in breadth at the base. The oral and ventral suckers are of equal size and have a spherical outline. Their diameters as measured in entire mounts are as follows:—

Diameter of oral sucker in mm.			Diameter of ventral sucker in mm.
0·07	...	...	0·06
0·06	...	...	0·06
0·07	...	...	0·07
0·06	...	..	0·06
0·07	...	...	0·07

The oral sucker is subterminal and lies on the ventral surface near the anterior end of the body. The ventral sucker is situated just in front of the middle of the body at a distance of 0·25—0·28 mm. from the anterior end and that of 0·27—0·33 mm. from the posterior end. The cavity of the anterior sucker is larger than that of the ventral sucker. The genital opening lies on the ventral surface near the left side border at the level of the intestinal fork at a distance of 0·4—0·66 mm. in live specimens and 0·18—0·31 mm. in permanent mounts from the anterior extremity. The genital atrium is so shallow that it is not recognisable in the

living worm, in which both male and female openings are seen lying close side by side. The mouth opens into a thick-walled pharynx of 0·04—0·06 mm. diameter. The oesophagus is fairly long about 0·12—0·18 mm. in length. The intestinal fork lies at the level of the testes much in front of the ventral sucker about midway between it and the oral sucker. The angle enclosed by it is less than a right angle. The intestinal caeca have dilated ends and extend as far as the posterior margin of the sucker measuring 0·22—0·31 mm. in length, while in *P. confusus* they are much broader and shorter ending much in front of the ventral sucker.

The reproductive organs except the coils of the uterus occupy the anterior half of the body. The testes are more or less spherical; they are situated outside the intestinal bifurcation and the caeca between the latter and the body-wall. They do not lie at the same level, on the other hand, the left testis lies in front of the other. The right testis is always a little larger having generally 0·07—0·09 mm. diameter and the left testis measures 0·05—0·07 mm. in diameter. From their posterior ends arise small vasa efferentia which run backwards as far as the cirrus sac near the left intestinal caecum to join the large vesicula seminalis. The cirrus sac has a large size in proportion to the size of the distome and thick muscular walls composed of longitudinally arranged fibres. It is 0·32—0·35 mm. long and 0·12 mm. broad near the base in entire mounts; when examined in sections it measures 0·25—0·28 mm. in length and 0·06—0·09 mm. in maximum breadth. It lies behind the left testis ventrally to the intestinal caecum of that side; it is more or less strongly curved anteriorly and consists of a basal saccular part containing the vesicula seminalis and pars prostatica and a small narrow tubular part, which leads to the exterior. The angle of curvature separating these two parts is nearly a right angle and lies

at a distance of 0·17 mm. from the base. The tubular part of the cirrus sac is 0·034 mm. broad and is about half of the length of the saccular portion, which is somewhat rounded at the base. The vesicula seminalis is U-shaped, has 0·03 mm. length and 0·05—0·07 mm. breadth and is filled with sperms. It opens by a small narrow duct of 0·006 mm. length and 0·003 mm. breadth into an ovoid or somewhat globular pars prostatica of 0·04 mm. by 0·029—0·03 mm. size. The epithelial cells of the latter, as already described in the other species, are much enlarged towards the lumen by the accumulation of prostatic secretion. The prostate cells of the usual pear-shaped form surround the pars prostatica and a great portion of the vesicula seminalis occupying the entire space between the latter and the muscular walls of the cirrus sac. The ejaculatory duct (cirrus) is 0·9—0·14 mm. long and 0·01—0·0136 mm. broad; it is not sharply separated from the pars prostatica. The epithelium of the narrow duct of vesicula seminalis, pars prostatica and cirrus is surrounded by a thick layer of longitudinal muscle fibres. The cirrus opens into a very small genital atrium, which is not easily visible in living specimens. The ovary is more or less rounded almost equal in size to the left testis measuring 0·05—0·07 mm. in diameter. It is situated in front of the ventral sucker invariably to the right side of the middle line partially overlapped by the right intestinal caecum and gives out near its inner posterior margin a short oviduct, which soon enters the ootype surrounded by the shell glands. The receptaculum seminis is a small pear-shaped sac placed close behind the ovary and the ootype to the right side of the ventral sucker; from its narrow proximal part arises a very small Laurer's canal which runs dorsally. The uterus arises from the right side of the ventral sucker and passes downwards nearer the dorsal surface into a convoluted mass which occupies the posterior right half of the body. This descending portion

after reaching the posterior end turns forwards ventrally to the same side till it runs transversely behind the ventral sucker to continue into the convoluted mass contained in the left posterior half. The ascending uterus takes its origin somewhat near the posterior end to the left side and runs forwards dorsally undergoing several convolutions before it passes into the thick-walled metraterm, which lies to the left side much in front of the ventral sucker dorsally to the cirrus sac. The metraterm is small, highly muscular and sharply set off from the uterus by its small diameter. It is 0·22 mm. long and 0·02 mm. broad and contains a narrow lumen of 0·008 mm. diameter which, however, becomes enlarged near the genital pore; its wall is composed of an inner cuticular layer surrounded by the two usual muscular layers. The genital atrium is very small being reduced only to an opening. The ripe ova have a deep brown shell, are elliptical in shape and measure usually 0·027 mm. (rarely 0·024 mm.) in length and 0·0136 mm. (rarely 0·012 mm.) in breadth. The vitellaria are confined to the ventral surface of the body beginning in the region of pharynx and terminating at about the level of the posterior margin of the intestinal bifurcation. They occupy obliquely the lateral areas between the oral sucker and intestinal bifurcation in front of the testes mainly to the outer side of oesophagus between it and the body-wall on each side, and overlapping the former for great part of its length. The yolk gland of each side consists of two branches placed close to each other; the follicles in each branch are pear-shaped and thickly crowded on each side of a central axis more or less in a regular manner like the leaves of a twig. The transverse vitelline ducts leave the gland near the intestinal bifurcation and run backwards longitudinally side by side till they cross the oviduct to open independently into a small but prominent reservoir, which lies close behind the inner part of the ovary.

The excretory bladder is V-shaped; it continues backwards into a small rudimentary median stem, which opens to the outside by a subterminal excretory pore situated on the ventral surface near the posterior end. The horns extend as far as the posterior margin of the ovary and have swollen extremities; they are not so widely separated as to give the bladder the shape of a broad V.

Remarks :—Up to the present time two species of the genus *Prosotocus*, *i.e.*, *Pr. confusus* Lss and *Pr. tener* Lss have been recorded and described. Klein (4) has referred tentatively both of them to the genus *Pleurogenes* in his key, although he sharply separates *P. confusus* from all the other species on account of the anterior position of the testes, *i.e.*, in front of the cirrus sac. Lühe (11) adopts the original classification and maintains the genus *Prosotocus* assigning *P. confusus* to it. While we are in entire agreement with this, we find *Pr. tener* to satisfy the definition of the genus *Pleurogenes* as Table VI and our key of this genus will show. We have compared the diagnostic features of the new species with those of *Pr. confusus* in Table V from which it can be seen that it differs from the latter in the following important features :—

(1) Equal size of suckers. (2) Greater length of oesophagus. (3) Size and shape of intestinal caeca. (4) Position of the ovary to the right side of the median line and the ventral sucker and its rounded shape. (5) Curved shape and transverse position of the cirrus sac. (6) Large number of follicles in the vitellaria and their position. (7) Subterminal position of the excretory pore and the presence of a rudimentary median stem of the excretory bladder. The less important points are (8) the differences in the shape and size of the body and (9) the size of suckers and ova.

6. Methods.

The Trematodes were fixed in Bouin's picro-corrosive formol, occasionally in corrosive sublimate or Zenker's solution. For entire mounts they were carefully flattened between two glass slides or between a glass slide and a long rectangular coverglass and transferred to the fixing solution. To prevent their separation a fine string was sometimes used to bind them together till the specimens were properly flattened and fixed. For entire mounts various stains such as borax carmine, alum carmine, dilute Delafield's haematoxylin, and haemalum were used, but the latter gave the best differentiation of various organs, and proved to be very useful and handy. For sections iron-haematoxylin was always employed.

7. Synopsis of the Sub-family Pleurogenetinae Lss.

We follow Odhner (15) in assigning this sub-family to the family Lecithodendriidae Odhner, which also includes the sub-family Lecithodendriinae Lss (=Brachycoeliinae Lss minus Brachycoelium). The definition of the Pleurogenetinae as given by Lühe in 1909 (11) and Odhner in 1911 (15) needs a certain amount of modification on account of the inclusion in it of the genera *Ganeo*, *Brandesia* and also of recently known species of other genera and the amended definition is as follows :—Body elliptical, elongated, oval or almost rounded in outline ; size small ; suckers not particularly strong; skin entirely or in anterior part of body closely beset with long pointed or rounded spines free at their ends, in hinder part spines may gradually diminish in number or disappear; gut with a small prepharynx and small rounded pharynx ; oesophagus absent, small or moderately long ; intestinal caeca small not reaching middle of body or moderately long, *i.e.*, reaching about

middle of body or long, *i.e.*, reaching near hind end; excretory bladder V or Y-shaped, but in the latter case with a small median stem; excretory opening terminal or subterminal and ventral; genital opening marginal on left side, or on ventral or dorsal surface near left side, in front of, or in the neighbourhood of ventral sucker; cirrus sac absent or parenchymatous (pseudo-cirrus sac) or large, muscular and strongly developed, pear-shaped or somewhat curved; vesicula seminis large and twisted; pars prostatica and prostate glands well developed; testes asymmetrically situated one behind the other or more or less symmetrically situated one on each side near body margin, in front of, near or behind ventral sucker; receptaculum seminis with a Laurer's canal arising from it always present; vitellaria simple, tree-shaped situated entirely in front of or in the region of a part of intestinal caeca; uterus is much convoluted and fills more or less posterior half of body; eggs when ripe have a deep brown shell and measure 0·02—0·038 mm. in length and 0·01—0·018 mm. in breadth; found in the gut of Amphibia (one species from Chamaeleon).

Key to the Genera.

Testes in anterior part of body in front of cirrus sac and in front of, or in neighbourhood of intestinal bifurcation.	Genital opening much in front of ventral sucker.	*Prosotocus* Lss.
	Genital opening in the neighbourhood of ventral sucker.	*Brandesia* Stoss.
Testes clearly behind intestinal bifurcation, behind or near posterior portion of cirrus sac.	Testes asymmetrically situated one behind another. Muscular cirrus sac absent.	*Ganeo.* Klein.
	Testes symmetrically situated at the same level. Muscular cirrus sac present.	*Pleurogenes* Lss.

I. Prosotocus Lss.

Body somewhat elliptical, oval or rounded under a slight pressure; size small; small anterior part of body strongly moveable; suckers about equal in size; intestinal caeca small never extending beyond ventral sucker; genital opening lies on ventral surface near left body margin in front of intestinal bifurcation nearer oral than ventral sucker; testes one on each side in front of or in the neighbourhood of intestinal bifurcation not entirely symmetrically situated; ovary pear-shaped or somewhat rounded, situated in median line or to right side closely in front of ventral sucker; vitellaria in anterior part of body obliquely situated on either side between oral sucker and testes; cirrus sac large and pear-shaped or curved, terminating in front of, or reaching posterior border of ventral sucker; uterus convolutions occupy mainly posterior half of body reaching hinder end, in front they may reach ventral sucker or extend beyond it; excretory bladder broad or narrow V-shaped with a terminal or subterminal opening; ova when ripe have a deep brown shell and measure ·024—·034 mm. in length and ·012—·0136 mm. in breadth; in small intestine of Amphibia.

Key to the Species of Prosotocus.

Ovary pear-shaped and median; cirrus sac straight with its long axis parallel to body-length and reaching near posterior border of ventral sucker ... ... *Prosotocus confusus* Lss.

Ovary somewhat rounded and to right side; cirrus sac curved and more or less transversely placed terminating in front of ventral sucker ... ... *Prosotocus indicus* n. sp.

2. Pleurogenes Lss.

Body oval, elliptical, oblong or somewhat spherical; size small; ventral sucker usually situated about middle of body, rarely in front of middle; oesophagus absent, short or long; intestinal caeca usually reach about middle of body length, *i.e.*, near ventral sucker, but in a few species extend as far as last quarter of body; genital opening on ventral or dorsal surface near left body margin at level of pharynx or near oral sucker except in *P. claviger* and *P. lobatus* in which it lies much behind oral sucker about midway between pharynx and ventral sucker; testes rounded or ovoid (lobed in *P. lobatus*) symmetrically situated one on each side near ventral sucker about middle of body or in a few species behind ventral sucker and middle of body; ovary in front of testes to the right side (in median line in *P. lobatus*) near or in front of ventral sucker; vitellaria composed of somewhat rounded or oval follicles regularly or irregularly distributed in anterior region of body in front of ventral sucker; cirrus sac large, pear-shaped, usually curved somewhat like S situated with its long axis parallel or somewhat transverse to the length of body; pars prostatica well developed, rounded or oval in outline; excretory bladder V-shaped with terminal or subterminal and ventral excretory opening; uterus convolutions confined to posterior half of body behind ventral sucker; ova when ripe have a deep brown shell and measure 0·020—0·035 mm. in length and 0·011—0·016 mm. in breadth; in duodenum and small intestine of Amphibia and chamaeleon (Pl. arcanum in cysts around pylorus and the surface of liver in American frogs).

Pl. claviger Rud and Pl. lobatus Ozaki differ from all other species of the genus in certain remarkable features, we therefore think it worth while to divide the genus into two sub-genera *Pleurogenes* and *Telogonella*.

Key to the Subgenera.

Intestinal caeca reach near middle of body about the level of ventral sucker; genital opening in front of intestinal bifurcation near oral sucker ... ... Subgenus *Pleurogenes.*

Intestinal caeca extend much behind ventral sucker reaching about the last quarter of body; genital opening at level with or behind intestinal bifurcation and about midway between pharynx and ventral sucker ... ... Subgenus *Telogonella.*

Subgenus Pleurogenes N. Subgen.

Suckers more or less equal in size; ventral sucker lies about middle of body; intestinal caeca reach about middle of body length; genital opening near left border at level of pharynx or near oral sucker; testes rounded or oval symmetrically situated at about level of ventral sucker near or just behind blind ends of intestinal caeca; ovary to right side in front of ventral sucker; in duodenum and small intestine of Amphibia and chamaeleon.

Key to the Species of the Subgenus Pleurogenes.

Oesophagus absent or short; genital pore near oral sucker at level with pharynx.	Oesophagus nearly absent; excretory pore subterminal and ventral.	Ventral sucker somewhat in front of middle; testes behind it.	*Pl. gastroporus.*
		Ventral sucker somewhat behind middle; testes close in front of it.	*Pl. sphericus.*
	Oesophagus short; excretory pore terminal.	Ventral sucker in middle; proportion in size of suckers 7 : 6.	*Pl. freycinati.*
		Ventral sucker somewhat behind middle; proportion in size of suckers 11 : 12.	Body oval; gut of Amphibia. *Pl. solus.*
			Body circular; gut of chamaeleon. *Pl. tener.*
Oesophagus long or moderately long; genital pore behind pharynx, *i.e.*, about middle of oesophagus or near intestinal bifurcation.		Ovary rounded; oral sucker larger than ventral sucker; found in lumen of gut.	*Pl. medians.*
		Ovary lobed; oral sucker slightly larger or smaller than ventral sucker; found encysted.	*Pl. arcanum.*

Subgenus Telogonella. N. Subgen.

Suckers unequal in size; oral sucker distinctly larger than ventral sucker ; ventral sucker quite in front of middle ; intestinal caeca very long extending as far as last quarter of body but not reaching hinder end; genital opening to the left side at level with or behind intestinal bifurcation and about midway between pharynx and ventral sucker; testes somewhat rounded or lobed, symmetrically situated slightly in front or just behind blind ends of intestinal caeca and always behind ventral sucker; ovary rounded or lobed, median or to right side close in front or to the side of ventral sucker; excretory bladder V-shaped with a terminal opening; ova 0·021—0·033 mm. in length and 0·012—0·016 mm. in breadth; in small intestine or bile duct of Amphibia.

Key to the Species.

Testes and ovary lobed; ovary median; genital pore much behind intestinal bifurcation; oesophagus small ... ... *Pl. lobatus.*

Testes and ovary with entire margins; ovary to the right side; genital pore at level with intestinal bifurcation; oesophagus moderately long. ... *Pl. claviger.*

3. Brandesia Stoss.

Body much flattened and somewhat rounded; size small; skin beset with spines; suckers well developed; pharynx present; oesophagus small; intestinal caeca terminating about level of ventral sucker; genital opening to left side in the neighbourhood of ventral sucker; testes symmetrically situated in anterior part of body in front of cirrus sac and ventral sucker; ovary lobed situated behind testes near median line on dorsal side at about level of ventral sucker; receptaculum seminis large; long Laurer's canal with

an opening far behind present; vitellaria composed of a small number of follicles present on either side in anterior part of body near oral sucker and in front of testes; muscular cirrus sac well developed and lies at about level of ventral sucker; excretory bladder small and V-shaped with a sub-terminal and ventral excretory pore; numerous uterus convolutions fill posterior part of body behind ventral sucker and dorsal half of anterior part reaching near vitellaria; eggs very numerous with a somewhat thin and deep brown shell measuring 0·030 mm. long and 0.013 mm. broad; live in cysts behind pylorus of frogs.

B. TURGIDA Brandes.

Length 2—2·5 mm.; body with a flattened ventral and very strongly arched dorsal surface; during extension hind end appears somewhat pointed; oral sucker situated ventrally behind anterior end measuring 0·55 mm. in diameter; ventral sucker behind middle near hind end of body with 0·33 mm. diameter; intestinal caeca terminate at the sides of ovary or about level of ventral sucker; testes and ovary lobed; in *Rana esculenta*. The above definitions of the genus and species are mainly taken from Lühe's Susswasserfauna Deutschlands on Trematoda (11).

4. GANEO Klein.

Body elongated, tongue-shaped, elliptical, oval or oblong; small or middle-sized; cuticle of whole body or anterior part covered with small spines; ventral sucker situated at border of anterior and middle thirds of body; oesophagus short or moderately long; intestinal caeca extending about or beyond $\frac{3}{5}$th length of body but never reaching hind end; genital opening lies ventrally near left border in anterior part about middle of oesophagus, or middle of distance between pharynx and intestinal bifurcation or in neighbourhood of the latter

and opens into a deep cavity formed by invagination of the body-wall (genital atrium or cloaca); testes in posterior part of the anterior third of body obliquely behind each other or one on each side; anterior testis lies anterior to ventral sucker and the posterior with its hinder border nearly at the same level with it, or the former in front of ventral sucker and the latter behind it, or both somewhat behind it; ovary behind testes and in front of middle half of body; vitellaria situated laterally in middle third of body; true or muscular cirrus sac absent; parenchymatous sheath surrounding male efferent apparatus, *i.e.*, pseudo-cirrus sac present or absent; latter elongated more or less straight, slightly or strongly curved reaching ventral sucker near its posterior edge; uterus convolutions transversely arranged occupying the space between intestinal caeca behind ventral sucker and reaching hind end of body; metraterm absent; eggs oval or elliptical with a dark brown shell measuring 0·026—0·034 mm. in length and 0·014—0·018 mm. in breadth; excretory bladder U-shaped with a very small posterior median stem; excretory pore terminal or subterminal; parasitic in intestine of Amphibia.

KEY TO THE SPECIES AND VARIETIES.

Pseudo-cirrus sac present; excretory pore terminal	Oesophagus moderately long; pseudo-cirrus sac more or less straight or slightly curved.	Caeca to $\frac{3}{5}$th body length. *G. glottoides*;
		Caeca reach near hind end. *G. glottoides var. africana.*
	Oesophagus small; pseudo-cirrus sac strongly curved.	*G. glottoides var. madrasensis.*
Pseudo-cirrus sac absent; excretory pore subterminal.		*G. tigrinum.*

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Plate I

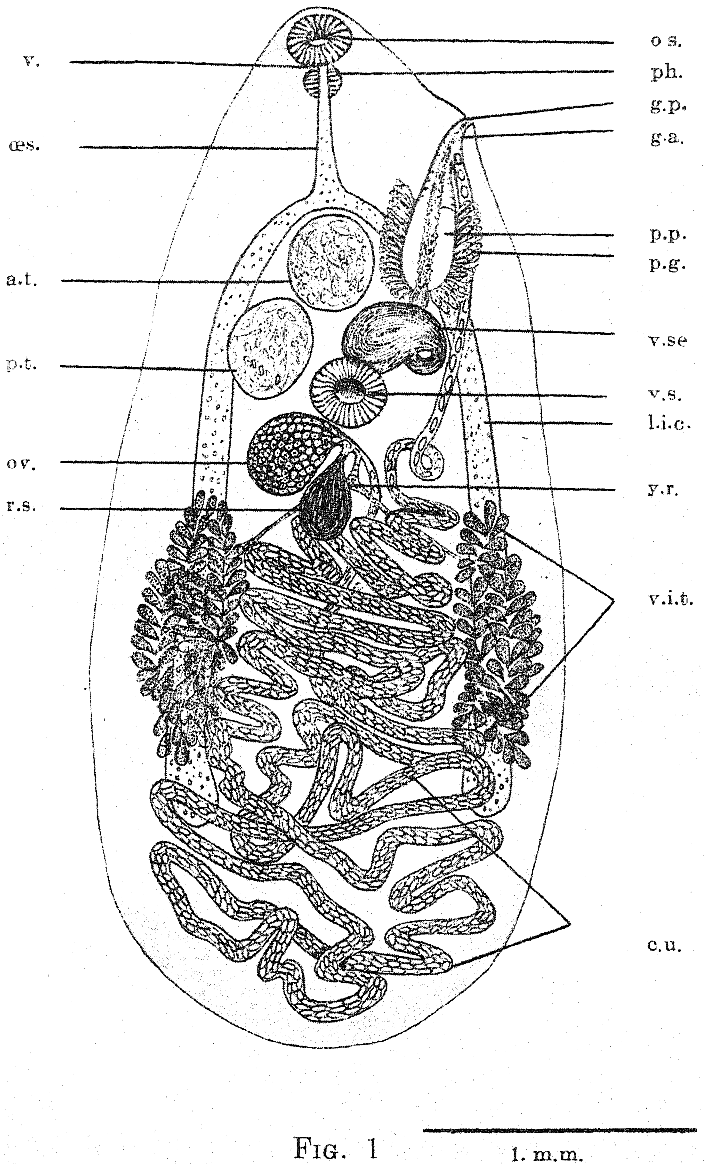

FIG. 1

Plate II

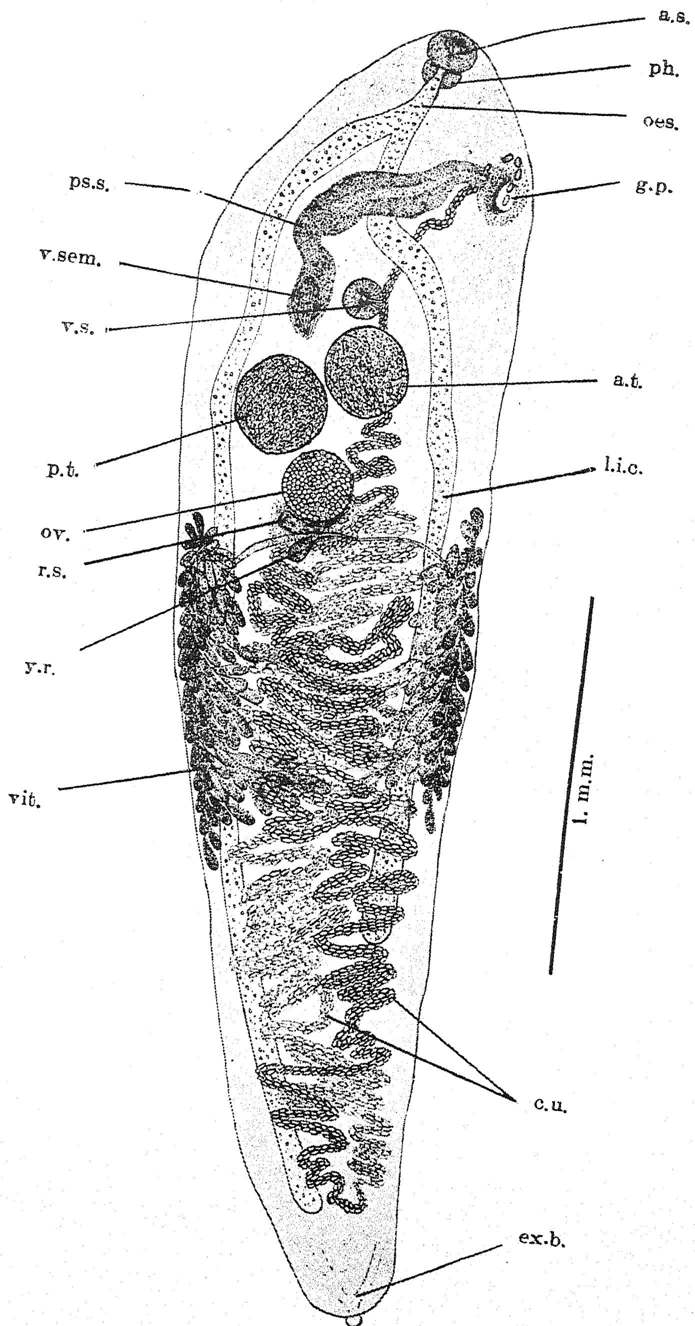

Fig. 2.

Plate III

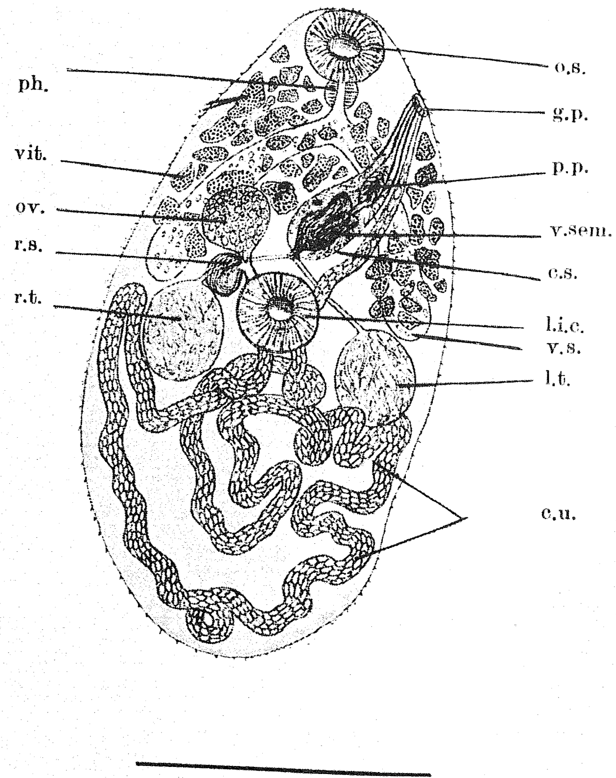

Fig. 3

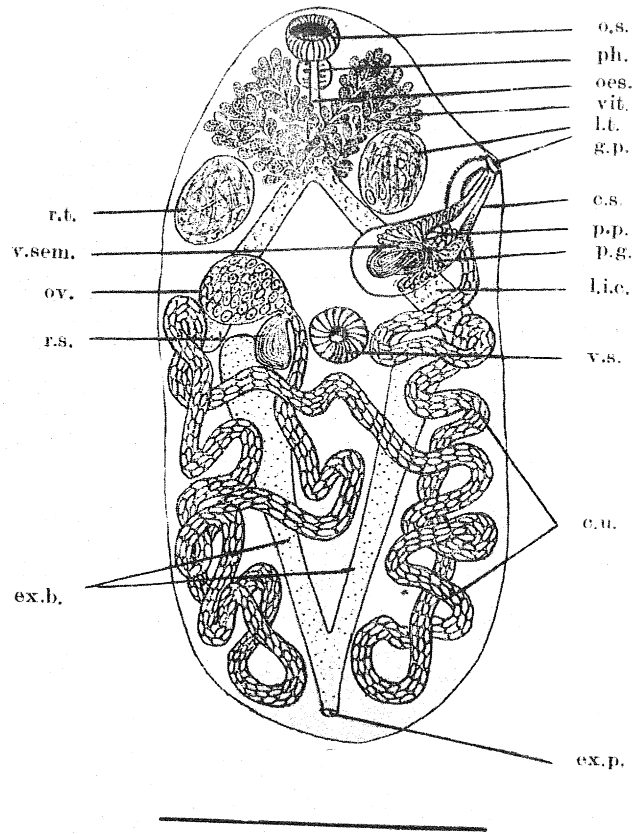

Fig. 4

g.o

g.a

p.g.

p.

Plate IV

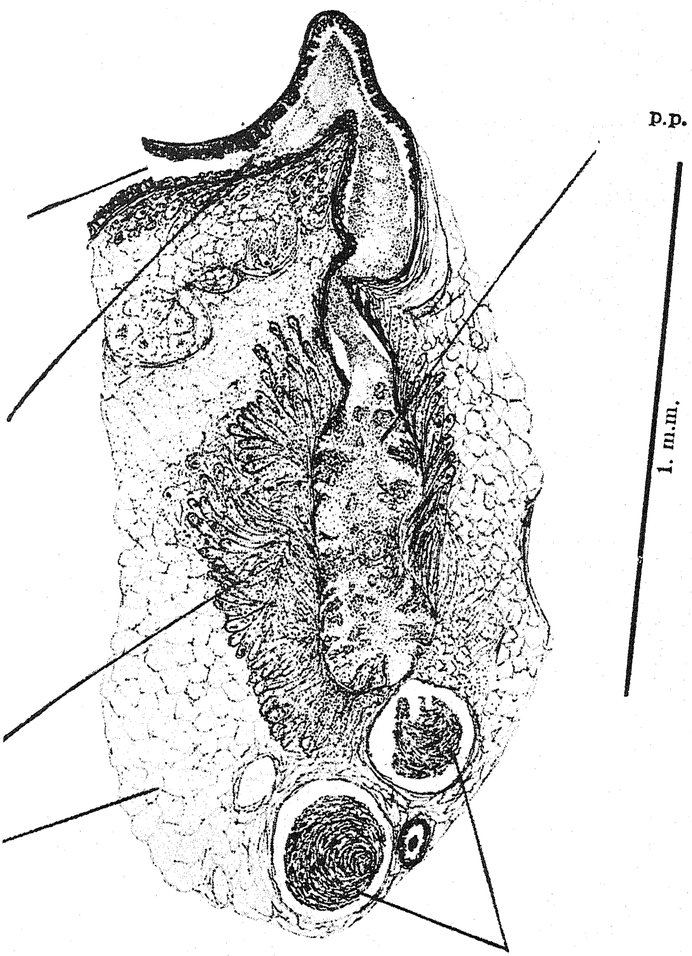

Fig. 5

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9. Explanation of Plates.

Plate 1. Fig. 1. Ventral view of *G. tigrinum.*

Plate 2. Fig. 2. Ventral view of *G. glottoides* var. *madrasensis.*

Plate 3. Fig. 3. Ventral view of *Pl. gastroporus* var. *equalis.*

Fig. 4. Ventral view of *Pr. indicus.*

Plate 4. Fig. 5. Longitudinal horizontal section of *G. tigrinum* showing male efferent apparatus and absence of pseudo-cirrus sac. Prostate gland cells lie freely in the surrounding parenchyma.

Cells of pars-prostatica are much distended on account of the flow of prostatic secretion through them.

Fig. 6. Part of the above section more highly magnified showing pars-prostatica and prostate gland cells.

Plate 5. Fig. 7 Microphotograph showing ventral view of *G. tigrinum.*

Fig. 8. Microphotograph of longitudinal horizontal section of *G. tigrinum* showing gonads, male efferent apparatus and ova.

Plate 6. Fig. 9. Microphotograph showing dorsal view of *G. glottoides* var. *madrasensis.*

Plate 7. Fig. 10. Microphotograph showing ventral view of *Pr. indicus.*

Fig. 11. Microphotograph showing horizontal longitudinal section of the cirrus sac, part of metraterm and ova of *Pr. indicus.*

Plate 8. Fig. 12. Dorsal view of *Pl. gastroporus* var. *equalis.*

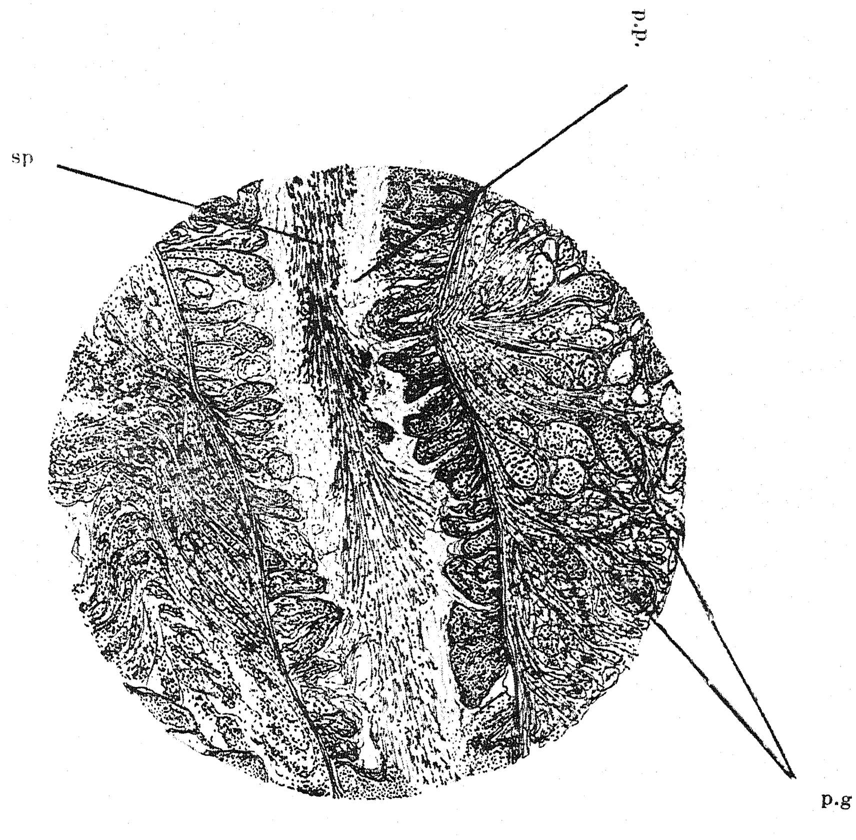
Fig. 13. Microphotograph of *Pl. gastroporus* var. *equalis.*

All figures except microphotographs are drawn with the aid of Spencer's Electric Drawing Apparatus.

Explanation of Lettering.

a. t., anterior testis ; c. s., cirrus sac ; c. u., uterus convolutions ; ex. b., excretory bladder ; ex. p., excretory pore ; g. a., genital atrium ; g. o., genital opening ; l. i. c., left intestinal caecum ; l. t., left testis ; oes., oesophagus ; o. s., oral sucker ; ov., ovary ; p., parenchyma ; p. g., prostate gland cells ; p. p., pars prostatica ; p. ph., prepharynx ; ph. pharynx ; p. t., posterior testis ; ps. s., pseudo-cirrus sac ; r. s., receptaculum seminis ; r. t., right testis ; sh. g., shell gland ; sp., sperms ; v. s., ventral sucker ; v. sem., vesicula seminalis ; vit., vitellaria ; y. r., yolk reservoir.

Plate IV



1.m.m.

FIG. 6

Plate V

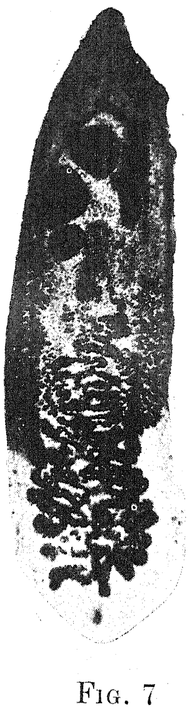


Fig. 7

Fig. 8

Plate VI

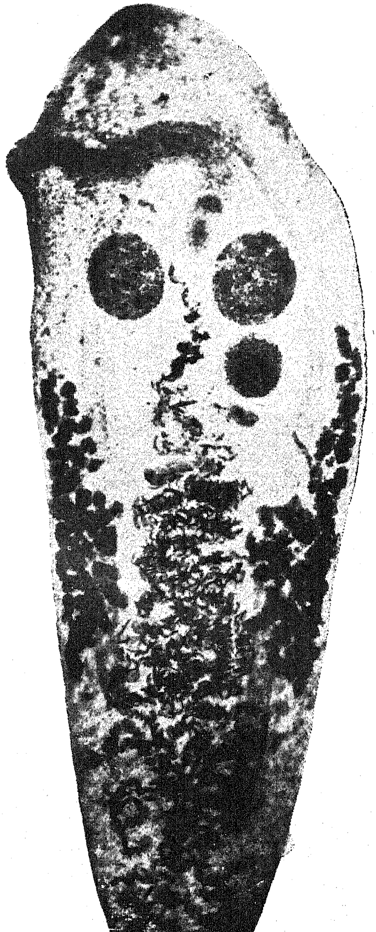


Fig. 9

Plate VII

Fig. 10

Fig. 11

Plate VIII

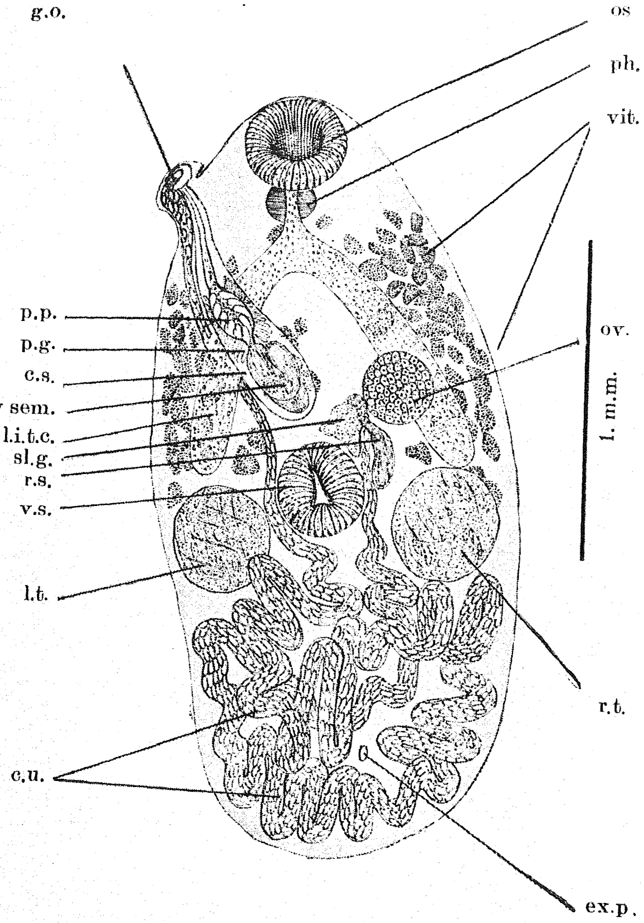


Fig. 12

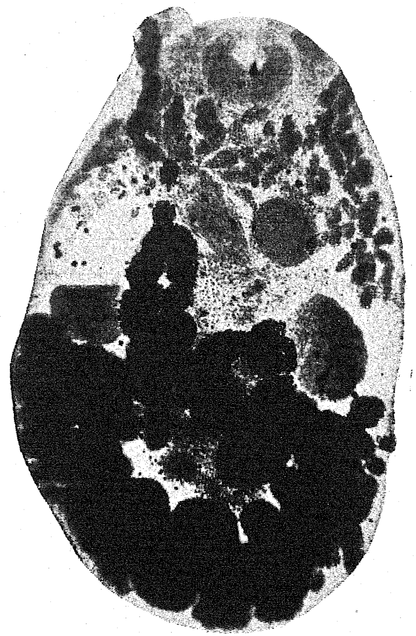


Fig. 13

TABLE V SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS PROSOTOCUS

Species.	Size and shape of body.	Size and ratio of suckers (oral : ventral).	Oesophagus.	Intestinal Caeca.	Genital pore.
1. *Pr. confusus* Looss, 1894 (1899).	1·36 by 1·0, somewhat rounded.	0.16 : 0·15. 16 : 15.	Small, 0·1 mm.	Broad; do not reach anterior border of ventral sucker, enclose at point of bifurcation more than a right angle; colour yellow or brown.	Half way between oral and ventral sucker at level of intestinal fork.
2. *Pr. indicus* n. sp. 1927.	0·6—1·1 by 0·42—0·52 in entire mounts, 1·2—2·4 long in live specimens; somewhat ovoid, but not rounded.	·06—·07 : ·06—·07. 1 : 1.	Moderately long 0·12—0·18 mm.	Reach posterior border of ventral sucker, enclose at point of bifurcation less than a right angle.	Nearer oral than ventral sucker at level of intestinal fork.

TABLE V SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS PROSOTOCUS—(*Contd.*).

Testes.	Cirrus Sac.	Ovary.	Receptaculum seminis and shell gland.	Uterus.	Ova.
1. More or less symmetrically situated near body margin outside pharynx and oesophagus; irregularly oval.	Extends near or a little behind posterior border of ventral sucker with its long axis parallel to body-length; elongated but not curved.	Pear-shaped; median, situated in front of ventral sucker.	To right side of ventral sucker.	Longitudinal loops one on each side connected by two transverse loops one behind oesophagus and other behind ventral sucker.	Elliptical; 0·034 by 0·013.
2. Asymmetrically situated outside oesophagus, intestinal fork and anterior part of caeca; ovoid.	Does not reach ventral sucker; placed transversely to body length; strongly curved consisting of basal saccular and terminal tubular parts.	Somewhat rounded; anterior to ventral sucker and to right side.	To right side of ventral sucker.	Longitudinal loops one on each side connected by one transverse loop behind ventral sucker.	Elliptical; 0·027 or rarely 0·024 by 0·0136 or rarely 0·012.

TABLE V SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS PROSOTOCUS—(*Contd.*).

Vitellaria.	Excretory pore and bladder.	Host.
1. Between oral sucker and testis on each side, not overlapping oesophagus or intestinal fork; follicles smaller in number and not thickly crowded.	Terminal; broad V-shaped without a median stem.	*Rana esculenta*, *Rana temporaria*, *Bufo vulgaris* *B. variabalis* and *B. calamita*, from Europe.
2. Between oral sucker and testes on each side overlapping partly oesophagus and intestinal fork; follicles larger in number and thickly crowded.	Subterminal; narrow V-shaped with a short median stem.	*Rana tigrina*, from India.

TABLE VI SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS PLEUROGENES.

Species.	Size and shape of body.	Position of ventral sucker.	Ratio in size of oral and ventral suckers.	Oesophagus.	Intestinal caeca.
1. *P. medians Olss*, 1894.	1·5—2·0 by 0·75—1·0; elliptical.	Almost middle, more in posterior half.	3 : 2 or 14 : 11.	Narrow and long; nearly equal to intestinal caeca in length.	Short; do not reach middle of body.
2. *P. freycineti*, Johnston, 1912.	1·45 by 0·89; oval	Middle.	7 : 6.	Thick walled; moderately short, smaller than that in *P. solus*.	Short; reach middle of testes but not middle of body.
3. *P. solus*, Johnston, 1912.	0·81 by 0·49; somewhat oval.	Behind middle.	11 : 12.	Narrow and short ...	Reach as far as anterior end of ventral sucker almost to middle of body.
4. *P. gastroporus*, Lühe, 1901.	When fixed without being flattened 1·65 by 0·77 and when flattened 1·95 long; oval or pear-shaped.	Somewhat in front of middle.	28 : 31.	Very small nearly absent.	Reach anterior border of testes almost to middle of body.
5. *P. gastroporus*, Lühe var. *equalis* n. var., 1927.	1·5—2·3 when alive and 1·1—1·7 in entire mounts; oval or pear-shaped.	Somewhat in front of middle more in anterior half.	1 : 1.	Nearly absent.	Reach anterior border of testes almost to middle of body.
6. *P. sphericus* (Klein) 1905.	In flattened 1·04 by 0·546 and in unpressed 0·54 by 0·39; oval when pressed; spherical when unpressed.	Somewhat behind middle.	14 : 15.	Absent.	Reach approximately anterior margin of ventral sucker almost to middle of body.

7. *P. arcanus* Klein 1905,—*Loxogenes arcanum* Nickerson (Stafford) 1900 (Osborn, 1912).	According to Stafford 1·9 by 1·28 and according to Osborn 2·6 by 2·3; spherical, ovoid or heart-shaped.	Somewhat in middle, or anterior rim in middle according to Stafford.	According to Osborn 0·02: 0·025 and according to Nickerson oral sucker is slightly larger.	Very short.	Short, less than half length; scarcely or do not reach middle of body.
8. *P. tener* Klein 1905—Prosotocus tener Looss 1899.	1·3 by 1·03 according to Looss and 0·4 by 0·5 according to Odhner; nearly spherical.	Somewhat behind middle.	11 : 12.	Short.	Reach anterior border of ventral sucker almost to middle of body.
9. *P. claviger* Rudolphi 1894—P. (Telogonella) claviger. 1927 n. sub-gen.	3·3 long; oblong with rounded ends.	Much in front of middle.	3 : 2 according to Looss.	Moderately long.	Broad and very long; do not terminate in front of $\frac{3}{5}$th body length.
10. *P. lobatus* Ozaki 1926—*P.* (*Telogonella*) *lobatus* 1927 n. sub-gen.	2·43 by 1·08 to 5·10 by 3·10 in specimens mounted under pressure.	Slightly in front of (cephalod) middle but in some large specimens at anterior one-third end.	5 : 4.	Small, longer than pharynx; 0·25—0·30 in length.	Very long, extending to last quarter of body length.

TABLE VI SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS PLEUROGENES—(*Contd.*).

Genital pore.	Testes.	Cirrus sac.	Ovary.	Receptaculum seminis and shell gland.	Uterus.	Ova.
1. Ventrally behind oral sucker, about middle of oesophagus.	Almost in middle of body at level with ventral sucker.	Longitudinally placed, posterior border touching ventral sucker.	At about $\frac{1}{4}$th body from anterior end outside right caecum; rounded.	To right side.	Longitudinal loops joined by one cross loop.	Oval; 0·03 by 0·016.
2. Ventrally alongside oral sucker.	Just anterior to ventral sucker.	Somewhat S-shaped; longitudinally placed altogether in front of ventral sucker.	At about $\frac{1}{5}$th body in front of right testis nearer median line.	To right side.	One transverse loop crossing middle line.	Elliptical; 0·0236 by 0·0117.
3. Ventrally on a level with pharynx.	On either side of ventral sucker.	S-shaped; ·245 long; longitudinally placed entirely in front of ventral sucker.	In front of and slightly internal to right testis at about $\frac{1}{3}$rd body.	To right side.	As in *P. freycineti*.	Elliptical; 0·02 by 0·01.
4. Ventrally near oral sucker.	On either side of ventral sucker.	Pear-shaped; reaches anterior margin of ventral sucker.	In front of right testis nearer median line at about $\frac{1}{4}$th body.	Near median line.	As in *P. medians*.	Elliptical; 0·023 by 0·011.
5. Ventrally near oral sucker at level with pharynx.	Placed more in posterior half than anterior half slightly behind ventral sucker.	Pear-shaped; longitudinally placed.	In front of right testis at a little more than $\frac{1}{4}$th body length.	To right side overlapped by caecum.	Two main and a third small longitudinal loop joined by one cross loop.	Elliptical; 0·02—0·023 by 0·011—0·012.

6. Ventrally near oral sucker.	Placed nearer than behind ventral sucker.	Pear-shaped; longitudinally placed; 2·36 long.	Obliquely in front of right testis; pear-shaped.	Somewhat to right side.	Convolutions somewhat to right side arranged in form of W.	Longish oval; 0·031—0·035 by 0·014.
7. On ventral surface according to Nickerson and Stafford, on dorsal surface according to Osborn, behind pharynx near intestinal fork.	At level of ventral sucker, *i.e.*, middle of body opposite each other or slightly in advance.	Long and narrow; longitudinally placed.	To right side of ventral sucker nearer right testis; lobed and somewhat pyramidal in form.	Shell gland median, receptaculum seminis to right side behind ovary.	Two longitudinal loops; left crosses ovary to enter metraterm.	Elliptical or slightly ovoid; 0·023—0·09 by 0·013—0·06.
8. Ventrally near oral sucker.	In front of ventral sucker.	Longitudinally placed in front of left testis.	To right side; pear-shaped.	...	Convolutions arranged in form of W.	Elliptical; 0·026—0·028 by 0·013—0·014.
9. Ventrally behind oesophagus at about level of intestinal fork, *i.e.*, far behind oral sucker.	Near hind end far behind ventral sucker.	Club-shaped; relatively small, somewhat transversely placed.	To right side of ventral sucker more behind it than in front.	To right side between ovary and ventral sucker.	Transversely arranged in four loops occupying more than half of body.	Elliptical; 0·033 by 0·016.
10. On dorsal side close to left margin midway between pharynx and ventral sucker.	Behind ventral sucker ventral to caeca in equatorial zone of body; irregularly lobed.	Slightly curved, has long and conical body; more or less transversely placed on ventral surface of left caecum; 0·45—0·92 by 0·04—0·16.	In median line in front of and dorsal to ventral sucker; irregularly lobed.	Receptaculum seminis behind and dorsal to ovary; shell gland median in front of former.	Complex loops more or less transversely arranged; metraterm set off from it by its greater diameter.	Elliptical; 0·021—0·022 by 0·012—0·013.

TABLE VI SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS PLEUROGENES—(*Concld.*).

Vitellaria.	Excretory pore and bladder.	Host.
1. Large number of large pear-shaped follicles regularly arranged on either side of oesophagus.	Terminal; narrow V-shaped.	*Rana esculenta*, *R. temporaria*, *Bufo calamita*, *B. vulgaris* and *B. variabalis*, from Europe.
2. A few rather large follicles in front of intestinal caeca.	Terminal; broad V-shaped.	*Hyla freycineti*, from Australia.
3. A few (nine) oval or pear-shaped large follicles on each side.	Terminal; broad V-shaped.	*Hyla aurea*, from Australia.
4. Large number of follicles of a somewhat irregular shape and large size extending from pharynx to end of caeca.	On ventral side in front of posterior end; V-shaped.	*Rana cyanophlyctis*, from India.
5. As in *P. gastroporus* Lühe.	Ventral, a little in front of posterior end (subterminal); V-shaped.	*Rana tigrina*, from Benares and Allahabad. (India).
6. A few follicles of a rounded form transversely rather than longitudinally situated in anterior third body on each side.	Ventral, subterminal; V-shaped.	*Rana hexadactyla*, from Southern India.
7. Pear-shaped follicles situated on lateral sides and ventrally to caeca and ovary between pharynx and testes.	Dorsal and subterminal; V-shaped.	Found encysted in liver of *Rana catesbiana* (Stafford), encysted at pylorus of other American frogs (Nickerson) or encysted on neck of urinary bladder of *Rana pipiens*.
8. On sides of oral sucker and oesophagus.	Terminal; V-shaped.	*Chamaeleo basiliscus*, from Egypt.
9. Pear-shaped follicles situated between pharynx and ventral sucker.	Terminal; V-shaped.	*Rana esculenta*, *R. temporaria*, *Bufo calamita*, *B. variabalis* and *B. vulgaris*, from Europe.
10. 5–10 groups of oval follicles on each side ventrally to caeca, between intestinal fork and testes.	Terminal; V-shaped.	Bile duct of frogs (*Polypedates buergeri*), from Japan.

TABLE VII SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS GANEO.

Species.	Size and shape of body.	Position of ventral sucker.	Ratio in size of oral and ventral suckers.	Pharynx.	Oesophagus.
G. glottoides Klein. 1905.	2·1—3·4 by 0·7*—0·94; tongue-shaped (elliptical or oblong).	At a little more than one-third body.	9 : 8. ...	0·086—0·09.	Long; 0·27.
G. glottoides Klein var. *africana* Serjabin. 1922.	2·3 by 0·51—0·76; elongated oval.	On the border of anterior and middle thirds.	1 : 1. ...	0·085—0·102.	long; 0·255.
G. glottoides Klein var. *madrasensis*, n. sp. 1927.	1·64—4·0 by 0·62—0·84; somewhat tongue-shaped or elliptical.	In front of anterior one-third behind intestinal fork.	7 : 6 or 6 : 5. ...	0·09.	Small; 0·14—0·21.
G. tigrinum, n. sp. 1927.	2·59—5·7 by 1·02 1·7 in live specimens and 2·4—3·7 long in entire mounts; elongated, somewhat oval with broad rounded hinder end.	At about one-third body length.	2 : 3. ...	0·07—0·12.	Long; 0·3—0·6.

* Breadth at the level of anterior end of vitellaria.

TABLE VII SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS GANEO)—*Contd.*).

Intestinal caeca.	Genital pore.	Testes.	Cirrus sac.	Ovary.	Uterus.	Ova.
1. Long, occupy about 3/5 body-length from anterior end.	In middle between pharynx and intestinal fork or sometimes lower in region of the latter.	Lie closely apposed obliquely one behind the other; anterior behind intestinal fork in median line, posterior to right side close to right caecum.	Pseudo-cirrus sac pear-shaped; 0·66—0·9 long covering ventral sucker dorsally by its hinder end.	Rounded; 0·18—0·21 in diameter close behind and contiguous to posterior testis near ventral sucker.	Windings compact and transversely arranged; occupy space between caeca behind ventral sucker; terminal windings small.	Long oval or elliptical, rounded at both ends; 0·028—0·034 by ·014—·018.
2. Very long; reach near hinder end.	At about level of middle of oesophagus.	Gonads widely separated; anterior occupies position of posterior testis of *G. glottoides* Klein, and posterior situated behind ventral sucker.	Pseudo-cirrus sac elongated and strongly curved; reaches ventral sucker; 0·7 long.	0·16 mm. in diameter; situated to left of median body line posterior to ventral sucker.	As in the type species.	Oval; 0·026—0·032 by 0·014—0·016.
3. Long; left smaller about $\frac{3}{4}$th body length and right reaches near hinder end.	At level of or close behind intestinal fork.	Lie somewhat obliquely near each other one on each side behind ventral sucker.	Pseudo-cirrus sac elongated and strongly curved with its basal portion to right side of ventral sucker.	Spherical; ·16 in diameter; lies behind right testis near median line.	As in the type species.	Elliptical; 0·027—0·03 by 0·017.

4. Long; reach $\frac{3}{4}$—$\frac{5}{6}$th body length, have swollen posterior ends.	At about level of middle of oesophagus or near its commencement.	Lie separated obliquely in front of each other; anterior behind intestinal fork and posterior in front of ventral sucker.	Cirrus sac or pseudo-cirrus sac absent.	More or less pear-shaped; 0·18—0·32 in diameter; lies behind ventral sucker to right side separated from posterior testis.	As in the above species.	Oval; 0·03 by 0·015.

TABLE VII SHOWING CHARACTERISTICS OF THE SPECIES OF THE GENUS GANEO—(*Concld.*).

Vitellaria.	Excretory pore and bladder.	Host.
1. From hinder border of posterior testis or ovary to a little distance in front of blind end of caeca or to about middle distance between ventral sucker and terminal end of body.	Terminal; U-shaped with a small median stem.	*Rana hexadactyla* from India.
2. From hinder border of posterior testis or ovary to about middle distance between ventral sucker and terminal end of body but terminating much in front of blind ends of caeca and occupying middle third length of latter.	As above.	A representative of Ranidae from Africa.
3. From anterior or posterior border of ovary to about half distance between it and terminal end of body and ending a little distance in front of termination of left caecum.	As above.	*Rana tigrina* from Madras (Southern India).
4. From behind ovary to a little distance in front of termination of caeca.	Sub-terminal; bladder as above.	*Rana tigrina* from Benares and Allahabad (Northern India).

SOME CESTODES FROM INDIAN FISHES, INCLUDING FOUR NEW SPECIES OF *TETRAPHYLLIDEA* AND REVISED KEYS TO THE GENERA *ACANTHOBOTHRIUM* AND *GANGESIA*.

BY

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(With 4 Text Figures and Plates I—VII including Figs. 1—48.)

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INTRODUCTION.

Little being known concerning the Helminth parasites of Indian fresh-water fishes, I started an investigation of the same about four years back. Although Woodland has, during this time, published some accounts of cestodes collected by him when at Allahabad, there is yet a good deal to be brought to light regarding these Indian types as the present paper (which is one of a series to follow) indicates. Still less is known of the Trematodes infecting the piscine species of the Indian fresh waters, which are also engaging my attention. I find that the fishes of Northern India, at least, are as rich in parasitic forms—Trematodes, Cestodes, Nematodes and Acanthocephala—as those of other parts of the world and present a great variety of interesting types. Two papers have already been published by me during the years 1926 and 1927, a third was read at the Lahore (1927) session of the Indian Science Congress and is in course of preparation for the press, along with a few others.

Family ONCHOBOTHRIIDAE.

Genus—ACANTHOBOTHRIUM.

Type—Acanthobothrium semnovesiculum Nov. Spec. (Figs. 1 to 9 and Text Fig. 1).

Host—Hypolophus sephen Mull and Henle (=Trygon sephen Cuv.)

Locality—Allahabad (Ganges and Jumna).

Habitat—Spiral value.

Time—July and August, 1926.

The Genus *Acanthobothrium*, established as far back as 1850 by Van Beneden, has been fully dealt with lately by Southwell (1925) in his valuable Monograph on *Tetraphyllidea* and defined as the second genus of the family *Onchobothriidae* (Braun, 1900, emended) with four bothridia

"each armed with two bifurcated hooks; each bothridium is divided into three loculi by two transverse septa."

The species here described falls within the genus *Acanthobothrium* as above defined. A single slide with one good specimen only was sent by me on August 13, 1926, to Dr. Southwell for identification as his Monograph was not available to me then. Unhappily the slide reached him in a broken condition; but still, he very kindly took the trouble of examining the preparation and regarded the specimen as *Acanthobothrium dujardinii*. For this kindness I am highly indebted to him. Subsequently, however, I obtained his Monograph (1925). On comparing my other preparations of the same material with the descriptions and figures given in it of *A. dujardinii* and other species of the genus, I felt convinced that my specimens differed markedly not only from *A. dujardinii* but also from other known species. Dr. Southwell, owing to the breakage of the slide, I think, did not see a complete specimen and hence was unable to form a correct idea of it. Therefore I am describing here this worm under the name *Acanthobothrium semnovesiculum* because it has a very prominent and characteristic vesicula seminalis.

The cestodes were obtained in abundance from three out of the five fishes dissected. They are almost all of equal length, but their size varies when fixed from 10 mm. to 15 mm. according to the condition of contraction of the specimen. During life they become considerably longer, often appearing as extremely fine delicate threads waving to and fro in the intestinal contents. It is difficult to remove them entire, with their scolices, as they are rather firmly attached to the walls of the intestinal valves. A number of isolated segments were, in each case, seen freely moving about like a trematode in the vessel in which the contents of the intestine were placed. These on being transferred to salt solution of normal strength were found dead next

morning; but on examination under the microscope still clearly showed that they were mature and ripe segments that had become detached from the parent strobila.

External Characters.—The cestodes when alive expand themselves to a length of 2 to 3 inches, but, on fixation in hot corrosive sublimate or warm alcohol, show the following mean dimensions in mm.

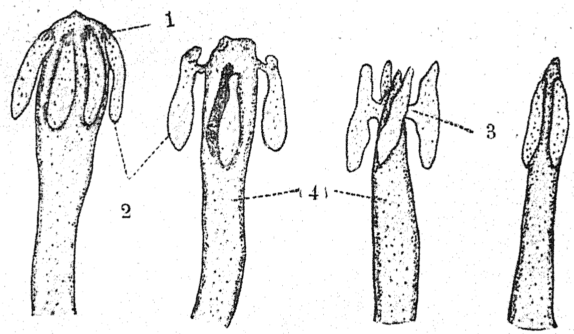
	Head.	Total length of hook.	Neck.	First distinct segment.	Middle segment.	Last segment.
Length	0·34	0·092	0·6	0·03	0·14	2·4
Breadth	0·26	...	0·13	0·16	0·18	0·3

The strobila is slender, linear and oval in cross section. Segments begin a short distance back of the scolex as crowded transverse lines and are at first a number of times broader than long, becoming squarish, then longer than broad. Maturing and adult proglottids are longer than broad, and free ones are still longer.

The total number of segments in an individual varies from 18 to 24, but the majority of specimens have 21 segments. As the proglottids are, as a rule, shed from the body on attaining maturity no ripe or gravid segments are met with in any of the permanent mounts of entire worms. The genital pores alternate irregularly (Fig. 1) and their position, which is marginal, varies a little about the middle line of the proglottids.

Head.—The head or scolex is nearly sub-quadrate with a somewhat broader hinder portion. In life it is capable of appreciable changes in shape and size. The bothridia are four in number, arranged diagonally on short pedicels which become manifest in the living worm only under a particular condition of the head (Text Fig. 1)).

They are directed backwards and assume on being fixed the form of an elongated oval or an egg having an average length of 0·3 mm. and an average breadth of 0·1 mm. These dimensions are capable of variation owing to great powers of contraction and expansion exhibited by them. In this species not only the anterior ends of the bothridia, as



TEXT FIGURE 1.

Showing alterations in size and shape of the head of a living *A. semnovesiculum:* 1. hooks; 2. bothridia; 3. bothridial stalk; 4. neck.

observed by Linton (1925) in *A. brevissimum* (= *A. paulum* Linton 1908), but also the posterior ends are very mobile and often expand themselves into narrow prolongations by a corresponding elongation of the entire head. The alterations in shape of the bothridia and head are diagrammatically represented in Text Fig. 1. Each bothridium is divided into three unequal loculi by two curved transverse costae; the anterior loculus is the largest, the posterior the smallest.

A distinct triangular pad (probably muscular as well as glandular) bearing at its apex a single accessory sucker is situated in front of each bothridium. The suckers are rather feebly developed, easily visible in the living state, but not perceptible in most permanent preparations. Their internal diameter in pressed specimens is about 24 μ. Overhanging each anterior loculus, between it and the triangular

pad, lie a pair of bifurcated hooks with unequal prongs of size given below :—

Total length of hook.	Length of handle to bifurcation.	Length of outer prong.	Length of inner prong.
85 μ to 100 μ	31 μ to 33 μ	42 μ to 55 μ	48 μ to 70 μ

The inner prong bears a small tubercle near its origin and the handle as well as the two prongs have a narrow cavity in the middle running throughout their length (Figs. 2 and 7).

Neck.—The neck is fairly long varying in length from 300 μ to 900 μ according to its condition of contraction, and does not bear spines. It is narrowest behind the head, gradually becomes broader posteriorly and passes imperceptibly into the commencing proglottids. Throughout its length it is traversed with a number of stout bands of longitudinal muscle fibres running through the head to the bothridia. These muscle bands are quite distinct in stained preparations of pressed material.

Internal Anatomy.

Muscular system.—The cuticle is smooth and thin: it is very transparent on the neck and head. The musculature of the strobila is weak but in the neck and a few anterior segments the longitudinal muscles are well developed, specially the internal layer. In hinder segments the longitudinal muscles appear in transverse sections, as a number of small bundles scattered in the parenchyma. No circular and oblique muscles were detected in any section ; they are therefore very feebly developed. The space between the cuticle and the layer of inner longitudinal muscles is occupied by spongy parenchyma with wide meshes.

Nervous system.—This was not studied.

Excretory system.—This system probably resembles that of the type species, but it is so poorly developed that the two small vessels on each side are frequently not seen at all.

Testes.—The testes (Fig. 3) show a regular arrangement. They are more or less uniformly distributed along the lateral proglottis margins except towards the anterior end where the two fields display a tendency to coalesce, through a number of smaller testes lying in between. In well-expanded maturing segments they are arranged in a single row on each side: but in some segments the two testes of an adjacent group alternate in position, one lying slightly outer than the other, so as to present the appearance of a double row. In the anterior segments and those contracted, they are more crowded but the two-field distribution is always maintained. Their number in developed segments varies from 42 to 55 and they are arranged in such a way that 23 of them lie on the poral side, 5 to 7 behind the genital pore, the rest in front of it. On the aporal side the total number is 24 or 25 and 3 to 6 form the anterior group connecting the lateral rows. As the younger proglottids contain a smaller number of testes, it appears certain that, with the growth in size and maturity of segments, new testes are formed at the anterior end and gradually shifted to one side or the other, hence the invariable presence of the smaller ones towards that end only. The long axes of the testes are parallel to the transverse axis of the proglottis and their size varies within fairly wide limits. The smallest of the anterior group, in the last but one segment of a specimen, measure 52 $\mu \times 48 \mu$ whereas the larger ones about the middle measure 80 $\mu \times 60 \mu$.

Vas deferens.—The cirrus is long, tapering and spinose. When everted it measures 0·352 mm. in length and 0·05 mm. in breadth at the base. The spines are long, delicate and bristle-like and line the cavity of the canal when

the organ is retracted within the pouch (Fig 9). The cirrus pouch is a conspicuous pyriform or pear-shaped structure, with rather weak walls, lying on the posterior side of the horizontal portion of the vagina. It extends towards the median line to about the centre of the segment and has an average size, in mature joints, of 160 $\mu \times 96 \mu$. In mature joints the retracted cirrus is partly folded in the pouch and continues antero-mediad as the vas deferens which forms a few coils before leaving the sac. Outside the pouch, the vas deferens crosses the vagina as a narrow oblique tube and, in the posterior four or five segments (Fig. 9), continues as a wider transversely convoluted tube, the seminal vesicle. The vesicle is full of sperms (Fig. 5), completely fills up the space between the testicular fields in front of the genital pore and terminates a short distance back of the anterior proglottis margin. It forms a prominent characteristic feature of the mature segments and is not known to occur in such a developed form in other species of the genus *Acanthobothrium*. In an allied genus *Onchobothrium*, in some species as *O. tortum* Linton (1917) a similar condition of the seminal vesicle is met with. It is not very convoluted in anterior segments, but takes the form of a median somewhat wavy tube which becomes less so as we proceed towards the anterior end of the worm.

Ovary.—The ovary is clearly visible from segments 8 to 10, though the testes can be distinguished from a few segments more anteriorly. It is a U-shaped organ situated along the posterior and postero-lateral margins with the two limbs of unequal length. The poral arm extends to the posterior margin of the cirrus pouch and the aporal one a little more anteriorly, reaching in some proglottids the level of the horizontal portion of the vagina. The length and breadth of the ovary varies from segment to segment. In the last joint of an average-

sized specimen it bears the following dimensions in mm. :—

Length of poral wing.	Length of aporal wing.	Greatest breadth (in front of shell gland).
1·1	1·25	0·16

The short ovarian isthmus opens into a median globular organ the "egg swallower" which has its walls provided with circular muscle fibres and continues posteriorly into a curved, highly muscular oviduct with large-nucleated muscles (Figs. 4 and 8). This muscular portion probably serves as an efficient "pumping organ" or "egg ejector." The oviduct then soon receives the narrow sperm duct from the vaginal seminal receptacle aud curves round backwards as the fertilisation canal. At the other end of the curve it is joined by the thin-walled common vitelline duct and terminates in the ootype (Fig. 4).

Vagina.—The vagina opens at the genital pore in front of the cirrus and exactly resembles that of *Phyllobothrium tumidum* Linton (1922) in the following particulars: "Its course is at first antero-mediad to near the median line, where it turns abruptly posteriad to follow the median line until near the posterior end of the proglottis, where it joins the germ duct." Near the exterior it is narrow ; it then enlarges in diameter, tapering more slowly to the curve, so that the antero-mediad portion is nearly fusiform. "Along the median line the diameter is reduced," and remains nearly uniform. The course along the median line is nearly straight, or in some cases, slightly sinuous, until a short distance in front of the ovary "where it is again dilated and functions as a seminal receptacle" Figs. 3 and 4).

Shell gland.—This is a distinct pear-shaped mass of granular cells disposed round the ootype and opening into it from all sides. It has a transverse diameter of 32 μ to 48 μ and lies in a clear space on the mid-line behind the ovarian isthmus, between it and the base of the ovary. Thus it is practically surrounded by the ovary. In position, nature and arrangement of the ovary and the shell gland this worm closely resembles *A. benedenii* Lönnberg (= *A. paulum* Linton) as described by Southwell (1925) on page 63 of his Monograph.

Vitelline glands.—The vitellaria begin near the anterior end of the segment and continue, as a single row of oval or rounded acini with a mean diameter of 0·15 mm., along the lateral margins of the proglottis, just outside the outer border of the testes and the ovary, to the posterior end. Their ducts are very narrow and often not seen at all.

Uterus.—The uterus lies along the median line as a thin-walled narrow structure extending from the region of the shell gland towards the anterior extremity of the proglottid. It is, in entire mounts, partly overlapped by the vagina and completely masked in front by the vesicula seminalis in all posterior segments. No eggs are seen in the uterus owing to the fact that the segments are detached from the strobila before they ripen as already mentioned.

Figure 4 gives a magnified view of the female ducts in the vicinity of the shell gland.

Affinities.—The character of the head, particularly of the bothridia and of the hooks, places this worm in the genus *Acanthobothrium*, but it cannot be referred to any of the known species. In the dimensions of its body it approaches *A. crassicolle*, *A. benedenii* and *A. dujardinii* but differs from them all in the non-spiny character of its neck, in the voluminous convoluted vesicula seminalis it possesses,

in the number of segments on the strobila and the size of its hooks. It can be further distinguished from—

(*i*) *A. benedenii*, by carrying a fewer number of segments on its body, by the smaller size of its hooks, by the regular disposition of its testes and the relatively larger size of the ovary.

(*ii*) *A. crassicolle*, by the smaller number of body segments, by the much smaller dimensions of its hooks, by the two-field distribution of its testes, by its U-shaped ovary and by the inner prong of each hook being longer than the outer.

(*iii*) *A. dujardinii*, by its smaller suckers, by a larger number of proglottids on the strobila and by a much larger number of testes in each segment.

Therefore taking into consideration the length of the worm, the nature and size of the bothridia and the hooks, the number of body segments, the number and arrangement of testes, and, above all, the presence of a conspicuous vesicula seminalis there can be no manner of doubt that this cestode furnishes features sufficiently distinctive to characterise it as a new species.

Diagnosis of A. semnovesiculum nov. spec.—Length 8—15 mm. Head distinct with four bothridia directed backwards and measuring, on an average, 0·3 mm. × 0·1 mm. Each bothridium divided into three unequal loculi; the anterior the largest, the posterior the smallest. A pair of bifurcated hooks of length 85—100 μ on the proximal border of the anterior loculus of each bothridium, inner prong of each hook longer than the outer. In front of each pair of hooks a triangular pad carrying a single accessory sucker of diameter 24 μ. Length of neck 0·3—0·9 mm., according to condition of contraction. Segments gradually increase in size progressively along the strobila. attaining a maximum in the last proglottid

which measures 2·45 mm. × 0·34 mm. in flattened mounts. Testes number 51 (42—55) in maturing segments, in two longitudinal fields with a tendency to coalesce anteriorly. Vesicula seminalis voluminous, prominently coiled in anterior half of a few of the hinder joints. Genital pores marginal, irregularly alternating, near middle of proglottis length. Cirrus long, spiny. Host, Hypolophus sephen.

Type slides containing stained preparations and also unmounted specimens are deposited in the collection of the Zoological Survey of India, Indian Museum, Calcutta (No.), and also in the reserve collection of the Department of Zoology, the University, Allahabad.

KEY TO SPECIES OF *Acanthobothrium*, AFTER SOUTHWELL, MODIFIED TO INCLUDE THE NEW SPECIES.

The prongs of each hook are equal in length 1.

The prongs of each hook are unequal in length 2.

1. Total length of hook 230 μ, each bothridium with a single accessory sucker ... *A. coronatum* Rudolphi, 1819.

   Total length of hook 140 μ to 170 μ, each bothridium with three accessory suckers ... ... *A. ijimai*, Yoshida, 1917.

2. Outer prong of each hook shorter than inner prong ... ... 3.

   Outer prong of each hook a little longer than inner prong ... ... *A. crassicolle*, Wedl., 1855.

3. Worms containing more than 200 segments ... ... 4.

   Worms containing less than 40 segments ... ... 5.

4. Total length of hook about 400 μ ... *A. macracanthum*, Southwell, 1925.

Total length of hook about 200 μ ... *A. herdmani*, Southwell, 1912.

Total length of hook about 100 μ ... *A. uncinatum*, Rudolphi, 1819.

5. Seminal vesicle distinct, voluminous; segments less than 25 (18—25), testes about 50 in each segment ... *A. semnovesiculum* Nov. Spec.

Seminal vesicle indistinct or absent ... 6

6. Segments less than 12, testes about 20 in each segment ... ... A. *dujardinii*, Van Ben., 1849.

Segments more than 30, testes about 45 in each segment ... ... *A. benedenii*, Loennberg, 1889.

Family PHYLLOBOTHRIIDAE.

Genus and Species—Inquirenda.

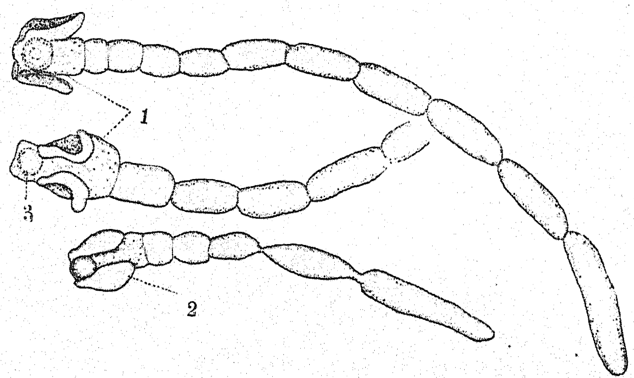
Host—Eutropiichthys vacha Day (=Pimelodus vacha Ham. Buch).

Locality—Allahabad.

Date—14th April, 1927.

I examined quite a large number of the above-named siluroid fish (commonly known as the butter-fish) for trematodes. In one of these, on the date indicated, I noticed four minute cestodes in the contents of the rectum. These, on removal to salt solution, were found very inactive; at least two of them were quite dead. On examination under the microscope they were found to contain no mature segment on the chain and hence their exact position, in the family, could not be ascertained. The single stained preparation made, also, does not show any internal organs (Fig. 10),

but the sketches taken in life, reproduced as Text Fig. 2, give a fair idea of the external anatomy of the worm.



TEXT FIGURE 2.

Sketches of three living examples of the Phyllobothriid cestodes from rectum of butter-fish: (1) Scolex; (2) bothridia; (3) special organ or sucker.

The cestode measures 1·5—2·0* in length and 0·15 in greatest breadth. The number of proglottids on the strobila of the largest of them is only 10, in others still less. The head or scolex is well marked off from the body. It measures 0·21—0·25 in length and 0·18—0·19 in width and carries four bothridia with simple edges. No accessory suckers could be observed on the bothridia owing to inactivity of the worms, but there appears to be present an apical organ or sucker (Fig. 10) anteriorly between the bothridia. The neck is most probably absent and the first segment, in these expanded specimens, is nearly as wide as long. The following proglottids are increasingly longer than broad, the last having a length five to seven times the breadth (0·68 × 0·14 in one individual and 0·65 × 0·1 in the other).

The presence of four unarmed bothridia, without costae (and separation of the segments from the chain before maturity) are undoubted phyllobothriid characters. Beyond this I am unable to say, just at present, concerning the genera or species as I could not collect more specimens owing to my

* All measurements given hereafter are in mm. unless otherwise stated.

absence from Allahabad during the summer months and the difficulty of obtaining these fishes later owing to their migration. With the return of winter they will again be procurable here and an attempt will then be made to obtain more of these parasites and to study them in detail. The occurrence of a phyllobothriid in a fresh-water siluroid is, however, remarkable.

FAMILY ICHTHYOTAENIIDAE.

Genus—ICHTHYOTAENIA.

Type—*Ichthyotaenia vitellaris.* Nov. Spec.

Host—Bagarius yarrellii Sykes (= Pimelodus bagarius Ham. Buch.).

Locality—Allahabad, India.

Date of collection—28th September, 1926.

Two specimens of a large species of tape worms clearly referable to the genus *Ichthyotaenia* Loennberg, 1894 (= *Proteocephalus* Weinland, 1858) were obtained on the above-mentioned date from one out of three siluroid fishes Bagarius yarrellii, dissected that day.

In general aspects this cestode resembles other Ichthyotaeniids and is like *Ichthyotaenia* (= *Proteocephalus*) *ritaii* which I described last year (1926) so far as external characters go, with the exception of the body size, the much larger head and the well-developed apical organ. The length is at least 25 cm. and the breadth of ripe proglottids, on fixation, 2 mm. and in flattened mounts 3 mm. The body does not narrow much at the head end (Fig. 11). The neck is fairly long and nearly of uniform thickness; its breadth, in permanent preparations, measures 1·2. It is terminated in front by the scolex which is about 0·8 wide and about 0·52 long. There is hardly any rostellar region and no spines were seen on the scolex, the suckers or the neck.

The apex of the head in front of the four suckers bears at its top an inverted cup-shaped or cap-like organ which

is very conspicuous and appears both muscular as well as glandular. Of the two scolices obtained one was partly crushed and the other was mounted entire. Therefore no sections of the scolex were cut and hence its minute structure cannot be indicated, but a fair idea of it can be formed from the balsam mount (Fig. 12). Owing to the cap-like arrangement of its muscles it seems to be more in the nature of a rudimentary rostellum than a fifth sucker. The suckers (diameter 0·16)* are spherical structures with muscular walls and anteriorly directed narrow openings having a diameter of 0·05.

The first traces of segmentation are visible from somewhere between 6 to 10 mm. behind the head region. The external division between the segments is not at all marked till about the middle of the strobila, and is faint throughout. It is difficult to determine the limits of a large number of anterior segments, but they are considerably broader than long. At a distance of 8 to 10 cm. behind the scolex the proglottids are only 0·15 long but their width is about 1·75. After another 6 cm. are passed, the segments (Fig. 13) are five to seven times as broad as long. The mature segments (with no uterine diverticula) are met with in the posterior third of the strobila and are nearly half as long as broad. It is only the extreme ripe proglottids that attain a length nearly equal to that of the breadth. The segments on the strobila are therefore generally broader than long; those near the posterior extremity (ripe ones) are a bit less broad than the mature segments lying in front of them. The number of proglottids on the strobila, owing to indistinctness of a considerable number of anterior joints and the breakage of the individual into pieces during removal from the host, cannot be precisely stated. In the mounted portions of a single specimen beginning from

* All measurements unless stated otherwise are from partly flattened mounts of the same worm.

the posterior end I counted 600 segments up to within 6 or 7 cm. from the anterior end. The total number can reasonably be put down about 700 or more. The genital apertures are just submarginal, irregularly alternating and situated a little in advance of the transverse middle line of the proglottid .

Internal Anatomy.

Muscular system.—The cuticle is very thin and easily drops off, in many places, in sections of preserved material. The usual two layers of longitudinal muscles are seen in transverse sections of mature proglottids (Fig. 16)—an indistinct external layer outside the nucleated region of the subcuticula, and a thicker internal layer of longitudinal muscles demarcating the cortex from the medulla. The fibres of the latter layer are strong but do not form compact bundles. They are either scattered singly in the parenchyma or are arranged in loose groups of two to six. In horizontal sections passing through the body-wall (Fig. 17) they are distinctly seen to branch freely and to form a layer of muscles arranged in network fashion with wide interspaces. A thin layer of circular muscle fibres is visible in transverse sections (Fig. 15) on the inner side of the internal longitudinal muscle fibres. The medullary parenchyma, particularly in the centre, is traversed by slender transverse as well as oblique muscle fibres like those described in *Ichthyotaenia gabonica* (Beddard, 1913). In fact these fibres are so close at places that one might well regard the whole parenchyma of the region to have become fibrous.

Excretory system.—The principal excretory vessels are four in number, two dorsal and two ventral, all lying in the medulla. The dorsal and ventral vessels of a pair are nearly of the same calibre. In the head region these longitudinal trunks form complete loops round the corresponding sucker and are connected with one another in the manner indicated (Fig.12).

Male generative organs.—The testes (Fig. 14) are numerous, 250—275 in fully mature segments and present the

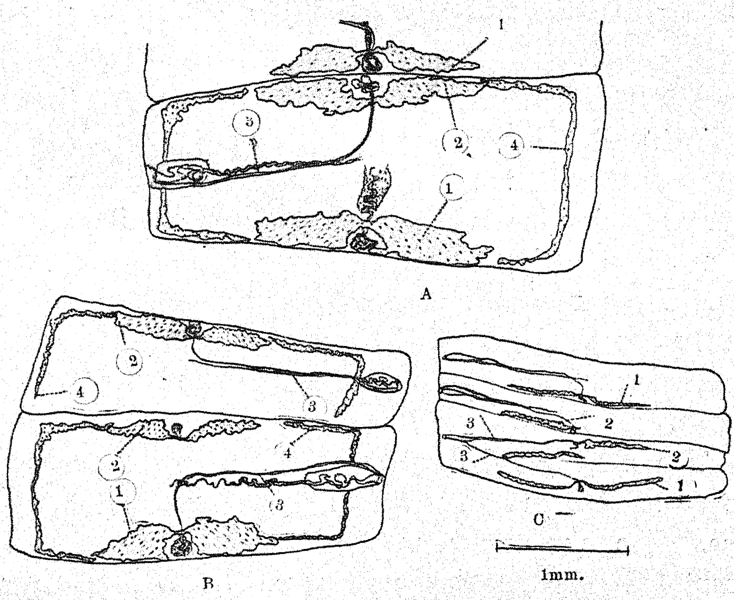
typical arrangement met with in the genus. They fill the whole proglottid between the vitellaria and the ovary, though often not quite so densely arranged in the median area. They lie along the dorsal surface of the medulla in a single field, only one deep, except towards the lateral regions where they are sometimes two deep. The testes begin to mature much earlier than the ovaries. In segments about the middle of the strobila (Fig. 13) and further anteriorly, where the female gland is yet a narrow streak, the testes have already assumed their characteristic shape and are seen loosely packed with testicular cells. In mature and ripening segments their cavities are full of masses of spermatozoa.

The cirrus sac is longer than broad, almost oval in form. It measures 0·14 along its widest part and extends medially to about 1/6th of the proglottid breadth. The sac has thin walls and lies peculiarly close to the ventral surface of the segment (Fig. 15) instead of occupying the usual median position between the dorsal and ventral body-wall. It pushes the layer of internal longitudinal muscles lying on its ventral side towards the cuticle, practically obliterating the cortex in that region. The unarmed cirrus lies feebly coiled within the sac. Its distal part is wider and nearly straight, but the proximal part is narrower and folded upon itself once or twice. It is surrounded by a narrow layer of circular muscle fibres outside which lie the gland cells. I never observed the cirrus in a state of protrusion.

The vas deferens has a few coils inside the cirrus sac, and after issuing from it forms, in ripe segments, many convolutions along its inward course. In transverse sections of such segments (Fig. 15) it occupies a considerable portion of the medullary region and is full of sperm masses. The tube forming the coils is thin-walled, of wide calibre, and extends medially to about the middle of the segment. The vas deferens, in maturing proglottids, is much less

convoluted and appears as a more or less wavy line passing directly towards the proglottis centre. The cirrus sac always lies posterior to the vagina and opens into the very shallow genital atrium situated close to the proglottid margin on its ventral aspect.

Female generative organs.—The ovary, as usual, lies along the posterior proglottis margin and consists of two fusiform masses of compact follicles united in the middle by a slender bridge. Though irregular in outline it is not produced into digitate processes. It extends on either side to about one-fourth the breadth of the segment from the lateral margin. In the anterior maturing segments it is very narrow, and although the testes are fairly developed it is seen as a mere wavy streak. In both of my specimens, at irregular intervals, the ovary presents remarkable abnormalities as indicated in Text Fig. 3, drawn from various



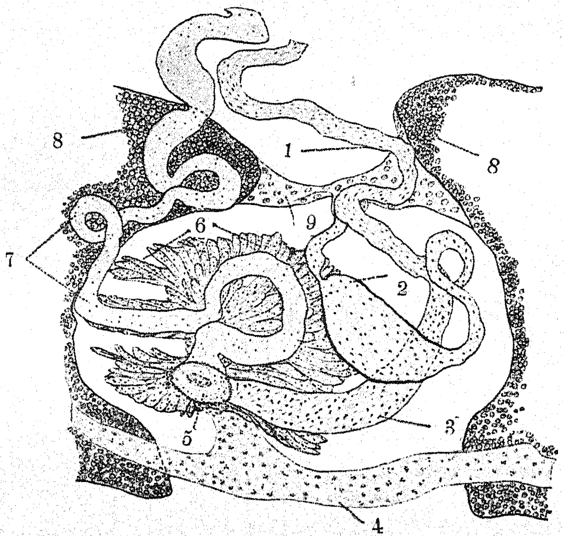
TEXT FIGURE 3.

Abnormal conditions of ovary and vitellaria seen on various parts of the strobila of *I. vitellaris.* A and B well-developed segments; C. anterior segments: (1) normal ovary; (2) abnormal ovary; (3) vagina; (4) vitellaria.

portions of the strobila of the individual. Fig. A represents a maturing segment in which, in addition to the normal ovary, is found another similar structure along the anterior margin. Curiously enough the vagina is connected with this abnormal ovary, the normal gland appears to go without it. At another place (Fig. B) is met with a segment having both an anterior and posterior ovary, but here the vagina is related to the latter as in the ordinary condition. In the first case the proglottid in front of the abnormal one has a normal ovary, but in the second case it has an ovary situated along the anterior margin only and the related ducts also show a corresponding variation. The vitellaria, in such segments, follow the female gland and develop on the anterior or posterior or both margins according as the ovary is present on one or both sides. In Fig. C is depicted another set of variations of the ovary seen in the more anterior portions of the strobila and repeated at two or three places. It can be seen from this figure that one-half of the ovary is developed in one segment, the corresponding half in the other; each of these halves has its own vagina, and there is no doubt of the two segments being quite independent of one another. A still more interesting feature is the occurrence of an incomplete segmentation (Fig. C) where two vaginae from different ovaries run into a common genital pore. I am unable to suggest any explanation of these often repeated abnormalities and am so far unaware of the occurrence of a similar phenomenon in any other cestode.

The shell gland is conspicuous and lies in the ovarian interspace between its two halves and the central connecting piece. The egg-ejector or "Schluckapparat" is less prominent and muscular but not large. It continues into a muscular dilated oviduct which after a single or double curve receives the vaginal duct and becomes continuous through the ootype into the uterine duct (Text Fig. 4).

The vagina is slightly dilated at its outer end and has its own separate coat of glandular cells throughout its length.



TEXT FIGURE 4.

Interrelations of female ducts in the inter-ovarial space of *I. vitellaris.* (1) vaginal duct; (2) oviducal bulb; (3) fertilisation canal; (4) vitelline duct; (5) ootype; (6) shell gland; (7) uterine canal; (8) ovary; (9) isthmus of ovary.

It opens into the genital pore or the shallow atrium from the dorsal side (Figs. 14, 15) and continues inwards along the anterior border of the cirrus sac. In maturing segments the whole of its horizontal portion lies clearly anterior to the vas deferens, but in fully mature and ripening proglottids the latter grows highly convoluted and overlaps the vagina here and there. On reaching the centre of the proglottis it takes an abrupt turn and runs medially backwards towards the ovarian bridge which it crosses dorsally.

The vitelline glands are very peculiar and resemble those of *Proteocephalus perplexus* La Rue, 1914 [= *Ichthyotaenia perplexa* (Meggitt, 1927)]. On each side they form a L-shaped structure extending along the lateral margin of the proglottis and continuing posteriorly towards the ovary which they often partly overlap (Fig. 16). The transverse vitelline ducts are not visible in toto mounts and can be made

out with difficulty in transverse sections. They appear to arise as slender tubes from the inner end of the posterior part of the vitellaria, on each side, and running behind or above the ovary unite into a common portion in the inter-ovarial space (Text Fig. 4).

The uterus is fully developed in ripe proglottids only. It can however be seen in maturing segments as a tubular structure lying in the median line, ventral to the vagina, extending from the anterior border of the proglottid to near the ovary. On its dorsal side it receives posteriorly a narrow wavy duct connecting it with the ootype. When full grown, it sends out on each side of the median stem five diverticula which are in close contact with one another (Fig. 16.) and contain numerous isolated eggs, each with its own coats. The external uterine pores are not obvious in permanent preparations of entire proglottids nor were any detected in the one series of transverse sections cut by me.

Systematic Position and Diagnostic Characters.

In the key to the species of the genus *Ichthyotaenia* (Meggitt, 1927) given on page 80, the present species falls under Section 6, Group P. In this group are included three species, namely, *I. macrocephala* * Creplin, 1829 ; *I. ritaii* * Verma, 1926 and *I. torulosa* Batsch, 1786. The species here described differs from all these in possessing a prominent cap-shaped apical organ, a peculiarly situated ventral cirrus sac and submarginal genital pore, an extension of the lateral vitellaria along the posterior proglottid margin, on each side of the ovary and a larger number of testes in each segment. It also differs in the number of uterine diverticula and other minor features. In the nature of its yolk glands it approaches *I. perplexa* La Rue as already mentioned,

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* I do not agree with Meggitt (1927) that these species appear similar. The number of testes in the first according to La Rue (1914) is 100—120 (not 100—200 as indicated by Meggitt) and in my species 150—200.

but that species is distinguished from mine by the absence of an apical organ in it, the occurrence of many uterine diverticula and other characters. The species is therefore new to science and named *Ichthyotaenia vitellaris* with the following diagnostic characteristics :—

Host—The siluroid fish, Bagarius yarrellii.

Length at least 25 cm.; breadth 2-3; scolex 0·8 wide, unarmed, with a conspicuous cap-like apical organ. Neck long. Proglottids number 700 or more. Genital pore close to margin directed ventrally or submarginal, irregularly alternating and slightly anterior to middle of proglottis margin. Genital ducts pass between longitudinal excretory vessels. Cirrus sac 0·25 × 0·14 situated close to ventral surface, reaches $\frac{1}{5}$ to $\frac{1}{6}$ across segment. Cirrus unarmed. Testes 250—275 in mature proglottids, in continuous dorsal field. Vagina anterior to cirrus sac. Uterine diverticula 5 on each side. Vitellaria L-shaped, lateral as well as posterior, following along the hinder margin they extend to the ovary and often overlap it partly.

Genus—GANGESIA. Woodland, 1924.

Type—1. *Gangesia pseudotropii*. Nov. Spec.

Host—Pseudotropius garua. Day (=Silurus garua Ham. Buch).

Locality—Allahabad (Ganges and Jumna).

Habitat—Duodenum and small intestine.

Quite a large number of this interesting cestode, remarkable in more ways than one, was obtained from twenty fishes purchased from the local markets from time to time during the last session. The number of worms infecting the various fishes, obtained on different dates, was recorded regularly and is reproduced below in Table I. The percentage of infection is fairly high. Sixty per cent of the fishes examined harboured the parasite, but the number of worms in a single host is usually limited to one or two; in

one instance only three individuals were found in a single host. As the majority of fishes were dead when bought, the parasites in some of them had also perished by the time they were dissected out.

TABLE I.

Date of collection.	Number of fishes examined.	Number of parasites obtained.	Region of alimentary canal.	Isolated segments.
15 11 26	3	nil	...	...
15 12 26	2	2 (both dead).	beginning of small intestine.	several, actively moving in rectum.
20 1 27	2	nil	...	...
4 2 27	7	6 (from 4 fishes).	not noted.	plentiful and alive even in fishes in which the parent cestode had died.
12 2 27	3	6 (2 from each fish).	duodenum.	not noted.
1 3 27	1	1	duodenum.	12 ripe and gravid ones from lower intestine and rectum.
4 4 27	1	3	duodenum and small intestine.	large number in hind gut.
14 4 27	1	2	beginning of small intestine.	a few in rectum.

Practically every infected fish carried, in addition to the parasite, a varying number of detached free segments—fully mature to gravid—in the lower intestine, particularly the rectum. Even in those hosts in which the worm had died these isolated proglottids were quite alive and, on

removal to salt solution of normal strength, began to display rapid movements. This shows that these free joints are more tenacious than the parent strobila. As a rule, they are plentiful in the rectum only but a few are often met with in the upper regions of the alimentary canal also, apparently on their way to the rectum from the anterior end of the gut where the actual worm lies attached.

External Anatomy.

As a mean of three specimens, measured alive, in a state of ordinary contraction, the following result was obtained:—

Table II.

Average dimensions in mm. of living examples of *G. pseudotropii.*

	Strobila	Scolex	Neck	10th segment	20th segment	27th segment	Last segment	Isolated ripe segment
Length	25·0	0·192	0·72	0·096	0·240	0·480	1·0	7·0
Maximum breadth.	0·18	0·240	0·08	0·096	0·125	0·176	0·16	0·6

The above dimensions, when compared with those of individuals fixed in hot corrosive sublimate, after being subjected to rapid motion in a tube, appear much shorter specially as regards breadth of strobila and length of posterior segments. On being so treated the worms die well expanded owing to muscular fatigue and appear dorso-ventrally flattened, oval in cross section towards the anterior end, but more depressed posteriorly. The hindmost segments in such preparations are approximately 1·3—1·8 long and 0·2—0·25 broad. Isolated ripe proglottids from rectum, fixed in the same way, measure 2—3 in length and 0·2—0·3 in breadth.

In permanent preparations of entire worms fixed after flattening between two glass slides the various parts measure as indicated in Table III.

TABLE III.

Measurements in mm. of an average-sized worm and its detached segments, fixed after flattening and mounted entire.

	Strobila	Scolex	Neck	Middle segment	Posterior segment	Isolated ripe segment	Isolated gravid segment
Length	30·0	0·288	0·4	1·36	2·72	6·56	4·4
Breadth	1·0	0·304	0·1	0·736	1·0	1·36	1·28

The cestodes are very delicate, usually coiled, and as the attachment between the segments of the strobila is very weak, it is difficult to separate them entire from the intestinal mucus. The hinder segments break off under the ordinary pressure of a glass slide, so the length can, at best, be only approximately mentioned as varying between 20—30 mm. and the number of proglottids in a complete specimen between 30—40. My largest example had only 36 segments, and in the case of a single individual occurring in one fish (Table I, Date 1. 3. '27) I counted 28 segments on the strobila and a dozen free proglottids in the lower intestine and rectum of its host.

The scolex is interesting in that it bears a characteristic "rostellum," *i.e.*, "prolongation of the apex of the scolex" which does not, however, appear capable of any great elongation. The dimensions of the scolex are given in the preceding Tables II and III. Its shape in the living condition is rather subquadrate (Fig. 19) but globular or pear-shaped when fixed. It is broadest in the region of the suckers; the measurements of its breadth noted in the above

tables are between external sides of the suckers. The rostellum is muscular and carries at its top a curious "apical organ" bearing a beautiful crown of large hooks on its circular outer margin. The hooks (Fig. 26) number 21 (17—22) and are arranged in a single row with their free ends directed towards the centre of the organ (when contracted), or pointing a little outwards (when rostellum is extended). Each hook has a bifid base (Fig. 20) and the two arms are of unequal thickness. The thicker arm is elongated along the principal axis of the hook, but the thinner one makes nearly a right angle with the main axis; their sizes are mentioned in Table IV.

TABLE IV.

Size of rostellar hooks in terms of μ.

	Part in front of basal bifurcation.	Thicker arm of base.	Thinner arm of base.
Length ...	35—40	18—20	13—16
Breadth...	8—10	5—6	3—4

The apical organ has a closed central cavity which is bowl or cup-shaped in the expanded condition (Fig. 27), but very narrow when contracted as seen in vertical sections of the scolex (Fig. 28). It does not seem to be capable of eversion, but it probably serves a boring function (for which it is admirably adapted) as also suggested by Woodland (1925 a) in *Proteocephalus beddardi*.

The four suckers are small, 80—100 μ in diameter, and thin-walled. Their rounded or oval openings face antero-laterally and are fringed with numerous minute curved

spinelets about 2 μ long. They are perceptible with difficulty in living specimens under gentle pressure, but are distinctly seen in sections under the high power of an ordinary Leitz microscope. The scolex, neck and strobila are all covered with cuticular spines or spinelets. The spinelets on the neck are finer and more dense, but those on the middle and hinder segments are thicker and less dense.

A distinct unsegmented neck is present. It is much longer and naturally thinner in living than in preserved specimens as can be judged from its measurements given in Tables II and III. The neck is broad at the base of the scolex and tapers to its narrowest part somewhat behind the middle of its length. It again broadens gradually and merges imperceptibly into the segmented region. A few of the anterior segments are hardly any broader than the neck in front. At a distance of nearly 6 mm. from the scolex the immature proglottids are approximately square in outline. They then become increasingly longer than broad, attaining about the middle of the body a length equal to two times the breadth. The posterior half-a-dozen joints are nearly two-and-a-half to three times as long as broad. On separation from the chain the segments increase further in length and are often five to six times as long as broad. The gravid proglottids are comparatively the widest near the middle, but appear to shrink in size owing to considerable lateral development of the uterine diverticula and loss of muscular tissues. All but gravid segments are nearly uniform in breadth with abruptly wide extremities. On account of ready separation of proglottids from one another under pressure the genital apertures could not be observed in a number of continuous joints. In small flattened portions of the strobila mounted on slides they alternate regularly and are situated on the proglottis margin, a short distance behind the middle transverse line. The vaginal opening lies posterior to that of the cirrus sac.

Internal Anatomy.

The cuticle is thick all over the body. It is nearly twice as thick on the middle of the strobila as it is on the neck (2·5 μ in cross section). The spines on maturing and ripening segments are stouter though less numerous than those on the scolex and neck. Their roots are deeply embedded, appearing in transverse sections as thick striations crossing the cuticle (Fig. 29). The circular musculature is very weak; in fact, it cannot be made out even in good sections. The longitudinal muscles are pretty well developed. In the neck (Fig. 25) and anterior segments they occur as scattered bundles much more numerous towards the periphery than the centre, there being no distinction between cortex and medulla. In maturing proglottids the outer layer of longitudinal muscles is very well developed and fills up the entire subcuticular area, but the internal layer consists of a slender band of scattered fibres widely separated from one another; so that the cortical region is but faintly marked off from the medullary. The meshes of the parenchyma are very wide and many ripe and fully mature segments, on being pressed between two slides, split up longitudinally into dorsal and ventral halves generally along the poral margin. This also indicates that the circular muscles are extremely poorly developed and that the parenchyma is very weak.

Four longitudinal excretory vessels occur in each proglottid on the internal side of the layer of inner longitudinal muscles but in transverse sections of maturing segments, in addition to these, are seen other longitudinal branches of equally wide calibre traversing the subcuticular as well as medullary regions. The ventral pair are wider than the dorsal.

The testes number 100 to 120 in maturing segments (Fig. 21) and 125 to 160 in ripening ones (Fig. 23). They are grouped in two clear fields running longitudinally anterior

to the ovary, midway between the proglottis centre and the lateral margin. In each field they are disposed in two rows, irregularly alternating with one another. In toto mounts of mature segments the oval ones measure 80—100 microns in length and 50—60 microns in breadth, and the circular ones have a mean diameter of about 75 microns. Their dimensions in ripe joints, similarly mounted, are larger (120—140 $\mu \times$ 75—100 μ).

The cirrus sac in permanent preparations appears as a thin-walled, flask-shaped (Fig. 22) or fusiform (Fig. 23) structure measuring in the former case $225\mu \times 100\mu$ and in the latter $260\mu \times 65\mu$. It contains inside it a feebly coiled cirrus which in no segment was seen everted. The cirrus sac passes between the dorsal and ventral excretory vessels and opens into the genital atrium; medially it extends to the testicular field but does not cross it. The vas deferens, on leaving the cirrus sac, is thrown into numerous close coils occupying the proglottis centre. Some of the coils are slightly wider than the rest and probably function as a seminal vesicle.

The ovary is bilobed and posterior. Each mass arises from a common transverse stalk and is either pear-shaped (maturing segment) or elongated (fully mature and ripening segments) with follicles arranged in lateral lobes. Immediately behind the transverse portion, "the isthmus," lies the globular egg-swallower or egg-ejector having a diameter of about 60μ (Fig. 31). Its walls are provided with large-nucleated circular muscle fibres and it is clearly visible in pressed specimens of ripe proglottids (Fig. 22). Posteriorly the egg-ejector opens into a muscular oviduct of uniform thickness (external diameter 16μ), which describes on one side of the median line a distorted figure of 8 or an outwardly directed U before it is joined by the still narrower vaginal duct (12μ thick). The oviduct then takes a backward course, turns inwards, and ascends anteriorly parallel

to its descending part. It then enters the shell gland which lies medially between the egg-swallower and the posterior curve of the oviduct. In some preparations the oviduct is irregularly coiled.

The vagina (Fig. 22) opens into the genital atrium just behind the opening of the cirrus sac and continues, along the posterior margin of the sac, as a narrow tube of diameter 15 μ running obliquely inwards until it reaches the centre of the segment. It then turns backwards and continues towards the shell gland to join the oviduct after crossing the ovarian isthmus on its dorsal side. A short length of the vagina (275 μ) in front of the isthmus is slightly dilated to form the indistinct receptaculum seminis.

The vitellaria are fully developed only in a few of the terminal segments completing maturation and in detached ripe ones, but they can be detected from about the middle of the strobila as faint streaks. Even at the height of their growth they are but narrow bands occupying a very short length along the lateral margins of the proglottid and extend from in front of the ovary to a short distance behind the genital pore. The aporal half is usually a little longer than the poral one (Figs. 22, 23). Narrow ducts arise from the vitellaria near their hinder extremities and run obliquely inwards and backwards to unite into the common vitelline duct in the vicinity of the ovarian bridge. The common duct crosses the egg-ejector on the side opposite to that on which the vagina passes and enters the ootype from its posterior side along with the oviduct. The interrelations of the female ducts in the vicinity of the shell gland are shown in Fig. 31, which is a photomicrograph taken from a permanent preparation of a well-flattened ripe segment. On account of the peculiar nature of its vitelline glands this species stands out unique among the *Multivitellata* (Southwell 1925), for I know of no other

cestode provided with paired lateral vitellaria confined to such a short portion of the posterior third of the proglottid length.

In the development of the uterus and the contained eggs also the species presents features of great interest. The uterus appears as a narrow median pillar in some of the posterior segments only and extends from the region of the ovary towards the anterior margin. It does not show any indication of lateral branching or of eggs even in the last segment of the strobila. As already mentioned, the ripening of the proglottids commences after their separation from the chain. The first change noticed in the uterus is its dilation towards the extremities owing to collection of eggs in it (Fig. 22). As more eggs are poured into it from the mature ovary it soon becomes full of them and begins to send out many lobed branches on each side of it. These lateral offshoots are at first short (Fig. 23) but gradually extend towards the periphery and ultimately, as the segment becomes gravid, they fill the whole of the interior with the progressive atrophy of other internal organs and tissues. In a gravid segment therefore is seen nothing but the uterus with its 30—40 wide lateral diverticula full of eggs and the vagina and cirrus sac which still persist (Fig. 24).

In ripe proglottids the uterus extends posteriorly to the ovarian bridge, sometimes overlapping it from the ventral side. It receives from the ootype a wavy uterine duct which opens into it dorsally about the level of the middle length of the vitellaria. This narrow portion of the uterus seems to be a part of the original pillar—seen in maturing segments—which has remained unmodified; the posterior prolongation of the uterus behind its opening is in the nature of a median diverticula. No uterine pores are present and the eggs or embryos pass out of it by a median rupture of the ventral wall of the proglottis which, by the time the segment becomes gravid, loses a good deal of its musculature.

The eggs are provided with three concentric membranes (Fig. 30), the outer two of which form loose coats round the embryo and respectively measure 35 μ and 22 μ in diameter; the innermost surrounds the embryo closely and has an approximate diameter of 13 μ. It is highly interesting to note that some of the eggs develop into embryos with well-marked necks and large vesicular bladders (150—160 μ in diameter) while still inside the proglottid and the original host. A number of these "bladder worms" or "cysticerci" with a distinct head, a neck and a bladder are met with in advanced gravid segments collected from the the rectum of the fish (Fig. 30). If this is a normal occurrence, the cestode assumes great importance as a probable single host parasite—a phenomenon which is very rare in the cestoda. But the presence of few individuals only, in each host, is strongly against the idea of auto-infection. Probably it is a case of regular precocious development; even then it has an important significance showing that at some future date the second host may be done away with if not already so. Anyhow it will be highly interesting to know the subsequent history of these embryos. I tried to keep some of the undeveloped eggs and the embryos living under laboratory conditions with a view to study their development, if possible, but my first attempts proved unsuccessful as I could not maintain them alive for a sufficient length of time. I intend to revert to this fascinating problem later and to try to investigate the life history of this remarkable cestode.

Systematic Position and Diagnostic Characters.

While engaged in the study of this interesting worm last summer I was confronted with a similar difficulty as beset Woodland (1924) in relegating his Wallago cestode to its systematic position and Meggitt (1927) in identifying some cestodes from Burmese snakes. I was placed in the predicament of having to classify a specimen,

as described above, distinctly *Ichthyotaeniid* but which could not be placed in any of the genera of the family as they then stood. In possessing an armed rostellum my type displayed a character of the genus *Gangesia* Woodland, 1924. But the two-field distribution of its testes prevented its inclusion in that genus as defined by Woodland (1924, 1925 a). This feature—testes in two lateral fields—characterises the genus *Ophiotaenia* La Rue, 1911 (= *Crepidobothrium* Monticelli, 1889) but it excludes forms possessing a rostellum armed with hooks. Only two other piscine species of the family *Ichthyotaeniidae* are known to me which have the testes arranged in the same manner as the species under discussion, namely, *Proteocephalus longicollis* Zeder (La Rue 1911) from the salmon, and "*Taenia*" *malopteruri* Fritsch, 1886 [=*Proteocephalus malopteruri* (Woodland, 1925 b)] from the Sudanese electric *eel*. The first of these does not possess an armed rostellum but the second does. The only way out of the difficulty was to either extend the scope of the genus *Proteocephalus* (*Ichthyotaenia*) so as to include forms with armed rostellum and testes in two fields as suggested by Woodland (1924), or, retaining the existing genera, to so emend the Woodlandian genus *Gangesia* as to cover cestodes like the present species and *P. malopteruri*. The former course if adopted would have made the genus a very heterogeneous group and hence was considered undesirable. Before I had made up my mind as to which of the two courses to adopt, I received a copy of a paper by Meggitt (1927) which solved my difficulty, as he has suggested therein a modification of the definition of the genus *Gangesia* along the lines desired by me. In fact the author has recast the classification of the entire family *Ichthyotaeniidae* in a manner which appeals to me very much. I therefore adopt the definition of the genus as given by him, but propose the addition to it of the words "the suckers, scolex, neck and strobila may or may not bear spinelets" because my

species unmistakably has the spinelets on all these regions. The amended definition of the genus *Gangesia* should thus read as : with the character of the family *Ichthyotaeniidae* (Meggitt 1927): with a scolex with rostellum armed with a circle of spines or hooks. The suckers, scolex, neck and strobila may or may not bear spinelets. Testes in one or two lateral fields. Vagina anterior or posterior to cirrus sac. Adults in fish.

The new species is therefore the fifth of the genus *Gangesia* as above defined, and differs from the four species included in it by Meggitt (1927), among other characters, by the restriction of its lateral vitellaria to a short portion of the proglottis length between the ovary and the transverse line passing through the genital pore; by its rostellum bearing an apical organ armed with large hooks having a bifid root; by the size of its eggs and by their often developing into the bladder worm stage while still inside the gravid proglottid, within the body of the original host.

The species G. *pseudotropii* may be distinguished as follows: length of strobila 20—40 mm. with a maximum breadth of 1 mm. Proglottids number 30—40 in mature worms; very narrow antero-posteriorly in front, square near the middle of the strobila and much elongated posteriorly. Mature segments separate from the chain before ripening, but remain in the rectum of the host until they become gravid and develop, in some of them at least, a bladder-worm stage from the contained eggs. Scolex about 192 microns long and 240 microns broad. Suckers small 80—100 microns broad, with projecting edges bearing close-set spinelets. Rostellum with an apical organ armed with 17—22 prominent hooks of length 53—60 microns. Neck and strobila both covered with minute spines or spinelets. Genital apertures marginal, behind the middle transverse line of the proglottid; vaginal opening always posterior to that of the cirrus sac. Testes 100—120 in mature, 125—160 in detached

ripe segments, arranged in two longitudinal fields anterior to the ovary. Vas deferens closely coiled in well-developed joints. Ovary bilobed, posterior; egg-ejector distinct in ripe segments, diameter 60 microns. Vitellaria lateral, short, between ovary and transverse line of genital pore; aporal half slightly longer than poral. Uterine, vaginal and vitelline ducts all dorsal to the ovarian isthmus. Uterus narrow, tubular, devoid of eggs even in the last segment of the strobila: in ripe proglottids with 30—40 lateral diverticula full of eggs. Eggs with three membranes; outermost 35 microns in diameter, innermost 13 microns in diameter closely investing the embryo. Some of the embryos develop a bladder (diameter 150—160 μ) and a neck while still inside the gravid segment in the rectum of the host. Habitat, duodenum and small intestine of Pseudotropius garua Day (a small siluroid fish) found in the rivers of the United Provinces, India.

2. *Gangesia bengalensis.* Southwell, 1913.

Southwell described a species of cestode, *Ophryocotyle bengalensis*, which he found in the intestines of Ophiocephalus striatus, Labeo rohita (1913 a) and Wallago attu (1913 b) from Bengal. His description is meagre and confined mainly to external features. Later, Woodland (1924) gave a fuller account of some cestodes, named *Gangesia wallago,* obtained by him from the intestines of Wallago attu at Allahabad. These were regarded identical with Southwell's *Ophryocotyle bengalensis* (Woodland 1924, 1925 a).

One of the D.Sc. Research Scholars of the Department, Mr. Dharam Narain, was engaged in working out the Wallago cestodes in 1924. But he had not completed his work when Woodland's paper (1924) appeared in print and he, naturally, gave up the idea of pushing this work further. He, however, retained some of his preparations and has now kindly passed them on to me. I am obliged to him

for this. On comparing these preparations and those I had made, from time to time, of specimens obtained from the same fish, with a new species which I have above described as *Gangesia pseudotropii,* I noticed that the specimens from Wallago attu were not all alike. This led me to make fresh collections and to study these forms in detail. As a result of this I find that there do occur in Wallago attu two distinct but closely related species differing from one another by well-marked features as indicated hereafter.

Woodland published his account after leaving India and had only preserved material with him. Hence it is not surprising that he failed to detect the difference between the two forms which have got mixed up in his description. It is, however, to be noted that at one time he also thought that there were two kinds of cestodes in this host as appears from the sentence "The larger of these cestodes differ greatly in length, thickness and form but I believe these differences are only due to local or general contraction, though at the time of collecting them they appeared to be separable into distinct kinds." From the account given by this author of his "*Gangesia wallago*" it is not easy to judge as to which of the two forms his description more agrees with. One of these, the smaller of the two, has a rostellum (Figs. 34 and 41) armed with about 51 large spines (average length 40 microns) arranged in two circular rows, and each mature segment (Fig. 36) contains about 200 testes: the total number of joints on the strobila is 200 or more. The other species is characterised by a rostellum with about 31 small spines (average length 22 microns) lying on a single circular row (Fig. 43). Each mature segment (Fig. 40) contains only about 100 testes, and although the number of proglottids in a complete worm is nearly 125 only the total length of the strobila far exceeds that of the other worm, owing to the larger dimensions of its joints, quite a number of which are longer than broad. For the

sake of comparison, in addition to camera lucida drawings, are furnished photomicrographs of mounted scolices and mature segments of both the forms side by side (Figs. 41, 43 and 42, 44). On referring to Southwell's papers (1913 a, b) it appears that the cestodes described by him all possessed two rows of hooks on the rostellum, the number of which as well as the size of the worms generally tallies more with that of the first of the two kinds distinguisheda bove. Therefore I regard that as *Gangesia bengalensis* and redescribe it as such. The other, larger form, is designated *Gangesia agraensis* in virtue of my having collected specimens of it from fishes obtained from various parts of the province of Agra and described, for the first time, as a new species, in this paper.

Most of the larger fishes dissected by me were infected with a varying number of these parasites. In one big fish examined lately I obtained ten specimens of *G. bengalensis* but only three of *G. agraensis*; whereas, in July, 1926, I found two large examples of the latter species only from a huge Wallago caught from one of the tanks at Mainpuri (Agra Division). A living worm, when removed from the intestine of the host, is much coiled and difficult to measure, but on being left undisturbed in salt solution for some time, it straightens out and gets fairly expanded. Measured in this condition the worms indicated the following dimensions in mm. :—

Length of strobila	Greatest breadth of strobila	Length of neck	Length of scolex	Breadth of scolex	Diameter of sucker
30—50	0·6—0·8	1·5—2·5	0·344—0·43	0·387—0·473	0·1—1·25

The average length given by Southwell (7·5) appears to be either of highly contracted individuals or of

incomplete worms, but the two long specimens obtained by him (of length 22 and 27) approach in size the living cestodes obtained by me. Some of my specimens mounted entire (deposited as type slide No. in the Calcutta Museum) measure as follows :—

	Strobila	Scolex	Rostellum	Sucker	Neck	Anterior segments	Early maturing segments	Posterior mature segments
Length	60·0	0·53 – 0·64	0·23 – 0·25	0·215 (diameter)	3·0 – 4·5	0·03 – 0·04	0·215	1·2 – 1·4
Breadth	1·5 (maximum)	0·64 – 0·86	0·25 – 0·32	...	0·75 (minimum)	0·8 – 0·85	1·0	1·3 – 1·5

The scolex (Fig. 34) with its four suckers and the rostellum is of the nature described by Woodland (1924), but the rostellar hooks are distinctly grouped in two circular rows (Figs. 35, 41), and the measurements given by him of these parts apply to both species taken together. The hooks of *G. bengalensis* are large, 37—44 microns long and have an irregular base with two rounded knobs, in different planes, one of which is oftener more prominent than the other (Fig. 41). They are all of one kind and shaped as shown in Fig. 33. The spinelets on the suckers are close-set, short, stoutish structures, easily visible under the high power of an ordinary microscope, and are arranged in six or more rows. They occur on half to two-third the margin of the sucker as observed by Woodland, but are seen in all of my preparations.

The neck (as an unsegmented portion of the strobila) is of the length noted in the above tables (Figs. 32 and 37). Southwell mentions it as 2·5 long, but Woodland considered the neck in contracted specimens "apparently absent" and very short even when extended. I presume the latter author had the other species (*G. agraensis*) under observation when describing the neck, or he was misled by

the wrinkled margin of the worms in correctly determining its extent.

A number of anterior segments are exceedingly narrow and the transverse wrinkling of the lateral margins makes it all the more difficult to determine the true strobilisation at this end. The first distinguishable joints are 15 to 20 times broader than long. The middle segments are nearly half as long as broad, but the posterior mature proglottids have a length nearly equal to the breadth ; only in some well-extended worms the segments are a little longer than broad. The total number of joints in a mature worm exceeds 200, the anterior 100 or 125 of which are extremely narrow and crowded together. It is only in segments following these that the reproductive organs begin to be clearly seen. The testes mature earlier than the ovary which attains its full grown form in the last 35 to 50 proglottids. Few or, in some cases, no ripe segments are met with on the strobila and the uterus when branched has 10—15 diverticula. No uterine pores are visible : the segments appear to ripen fully after detachment from the parent body and probably after passing out of the intestine of the host. The sexual openings are irregularly alternate and marginal ; in no case do I find them 'almost all on one side' as observed by Southwell (1913 a). They lie on the middle transverse line of the proglottis or a little anterior to it, varying in position according to the condition of contraction of the part.

The arrangement of the genitalia and their form can be seen from the Figures (36 and 42) provided. The two lobes of the ovary are transversely elongated and connected by a narrow median isthmus. The widest part of the ovary, antero-posteriorly, even at the height of its development hardly exceeds a quarter of a mm. in length. The uterine diverticula, as described by Woodland, occur in the other species, *G. agraensis*. The vagina is feebly dilated

near the opening and does not show any other dilation. Its transverse part varies in position with regard to that of the cirrus sac in different segments. Sometimes it is anterior and sometimes posterior to the cirrus sac, and so is the case with the relative openings of the two. The testes lie in one continuous field as stated by Woodland, but their number, in each segment, is 200 or more; the largest of them, in well-flattened mounts, never exceeds in length 70 microns. The cirrus sac is a narrow elongated structure which in the unevertedand uncontracted state extends to about one-third the distance across the proglottis. The cirrus lies coiled inside it and has a wider extremity. The figure of the mature segment given by Woodland agrees with that of the new species, but the sketches of the scolex and its parts are of preparations from this species.

The excretory canals are double on each side, a ventral and a dorsal, situated close to the lateral border of the testicular field; they are nearly of the same calibre.

The species *G. bengalensis* should therefore be distinguished as such:—Length of strobila 30—50 with a maximum breadth of 0·8. Proglottids 200 or more, very narrow antero-posteriorly in front, nearly square or somewhat longish posteriorly. Lateral margin of body often much wrinkled. Scolex average size 0·387 long and 0·43 broad. Suckers with small openings and projecting edges 0·1—0·125 in diameter, several rows of close-set spines along $\frac{1}{2}$ to $\frac{2}{3}$rds the margin. Rostellum with about 51 spines arranged in two circular rows alternating with one another; all of one kind, 37—43 microns long. Neck laterally wrinkled, nearly 2·0 long. Testes 200 or over, rounded in outline; average size in pressed mounts 50 microns in diameter. Strobila without or with few ripe segments, uterus unbranched or with 10—15 diverticula in the posterior proglottids. Genital openings on the mid-transverse margin of the

proglottis or slightly anterior to it; the cirrus sac and vaginal openings vary as to which is anterior. Cirrus sac extends medially about $\frac{1}{3}$rd across the segment. Habitat: intestine of Wallago attu Bleek., Ophiocephalus striatus and Labeo rohita, rivers and lakes of India.

3. *Gangesia agraensis* Nov. Spec.

This species occurs mixed up with *G. bengalensis* as already mentioned when describing it. Some of the features distinguishing these two species (from a common host) have also been noted in the same connection and others are enumerated later. This form does not appear to be so common as the other but I have often come across fishes infected by it alone. More commonly, particularly at Allahabad, the two species are found to exist together in the same individual, occupying any region of the alimentary tract from duodenum to commencement of large intestine, and occasionally in the stomach.

The worms when full grown are much longer than *G. bengalensis*. One of my complete specimens in salt solution measured more than 100 mm. in length and another about 80 mm. The average dimensions in life, taken as a mean of four individuals, are as follows :—

Length of strobila	Greatest breadth	Length of scolex	Breadth of scolex	Diameter of sucker	Length of neck
100	1·4	0·3	0·36	0·125	1·5

From the above table it is clear that although this cestode is longer and thicker than the other it bears a comparatively smaller scolex and shorter neck. A specimen, mounted entire after flattening, (deposited as

type slide No. in the Calcutta Museum) shows the following dimensions :—

Part I.

Head and Neck.

	Scolex (contracted partly)	Rostellum	Sucker	Rostellar hooks	Strobila	Neck
Length	0·41	0·194	0·19	20—25 μ	210	3·0
Breadth	0·60	0·258	0·17	...	2·5	0·58

Part II.

Segments of the Strobila.

	Anterior ones.	Early maturing, 20 mm. behind scolex.	Mature, 45 mm. behind scolex.	Just ripening, 60 mm. behind scolex.	Ripe, 100 mm. from scolex.
Length	0·064	0·13	1·65	1·72	2·60
Breadth	1·250	1·58	1·60	1·62	1·72

The head or scolex displays the characteristic structure of the genus in that it possesses a muscular rostellum armed with a fringe of hooks. They (the hooks) are all alike (Fig. 39) and arranged in a single row along the circular margin of the rostellum (Fig. 43). In perfect scolices they number 31 but get easily dropped in removing the worm from its host, or are of a deciduous nature; for, in many of the mounted specimens, there are gaps in the circle and the number of hooks varies according to these gaps. Their shape is indicated in Figs. 39 and 43, and their total length varies from 24 to 26 microns. The suckers are nearly

circular in outline with large openings and bear only one (at places occasionally two) row of minute spines visible under the high power of an ordinary microscope.

The neck, partly owing to its greater breadth and partly due to the smaller size of the scolex, is not so well marked as in the other sister species. In the contracted condition it is about as thick as the head and hardly one mm. long, but when expanded (Fig. 38) it is distinctly narrower than the head and twice as long as it is when contracted. It continues imperceptibly into the anterior proglottids which are at first twenty times broader than long, but become comparatively longer much sooner than in *G. bengalensis*. At a distance of one-fourth the body length from the anterior end their length equals the breadth and they commence to ripen (*i.e.*, the uterus begins to branch and to show eggs inside it). About the middle of the strobila the segments (Fig. 45) are fully ripe, with well-developed uterine diverticula and are, when expanded, nearly one-and-a-half times as long as broad. The following proglottids are still longer than broad and begin to turn gravid. The total number of segments on the strobila is approximately 125 or more, but never exceeds 150. The mounted specimen whose dimensions are given above has about 120 easily countable joints, 75 of which possess uteri with diverticula (from just ripening to gravid). The genital apertures alternate irregularly and lie on the proglottis margin clearly cephalad to the middle transverse line.

The reproductive organs have the same general disposition as in the other species from the same host, but they mature and ripen more quickly in this form as is evident from the very large number of ripe segments on the body. In fact, more than half the strobila in this cestode is made up of segments varying from ripening to gravid. The bilobed ovary when fully formed (Fig. 40) is fairly big. Each lobe is one-fourth to one-third as long (antero-posteriorly) as the containing proglottid and is connected with the other by an

isthmus near the middle of its length or further caudad. The uterus, in ripe segments (Fig. 45), is copiously branched and extends to the posterior limit of the segment ventral to the ovary. The number of uterine diverticula varies between 20 to 30, and 3 to 5 uterine pores are clearly visible in some of the stained preparations (Fig. 47) of ripe and gravid joints as well as in transverse sections of the same (Fig. 46). Most of the embryos probably escape into the intestine of the host before the isolation of the segments from the strobila as a number of posterior proglottids contain very few or practically none of them. The vagina is like that of *G. bengalensis* and its position, relative to that of the cirrus sac, as well as that of their openings is also similarly variable. The testes lie in one continuous field several layers deep and number about 100 or more. They are generally circular in outline or are transversely elongated (may be due to pressure). The largest of the rounded ones in pressed specimens of ripe segments has a diameter of 107·5 microns and the smallest of 64·5 microns. The vitellaria occupy the usual marginal position as broad bands extending from one end of the proglottis to the other, appearing very nearly continuous from segment to segment. Both testes and vitellaria are medullary in position (Fig. 46). The cirrus sac is not quite so narrow as that of the other species *G. bengalensis* and rarely extends to one-third the distance across the proglottid. It contains inside it a coiled cirrus which when fully everted (Fig. 48), under pressure, is nearly a millimetre or more long. On leaving the cirrus sac the vas deferens, in mature and ripe joints, widens and gets convoluted along its inward course. It terminates imperceptibly in the centre of the segment. The eggs contained in the uterus possess three envelopes the outermost is very thin and measures 66 microns in eggs liberated in salt solution. The dimensions given by Woodland (1924) in connection with *G. bengalensis*, of eggs from the intestine of the fish do probably apply to this cestode.

The excretory longitudinal vessels, as seen in stained preparations and in living worms under pressure, are two on each side. They are situated at a distance of about one-fifth the breadth of the segment from the lateral margin. The ventral vessel is the wider of the two (Fig. 46) and gives a pretty wide transverse branch close to the hinder border of each proglottid.

From the foregoing account it is manifest that, in addition to the characteristics already pointed out when redescribing *G. bengalensis*, this species further differs from it (i) in possessing only one or at places two rows of spinelets on the suckers instead of several rows ; (ii) by carrying a large number of ripe and gravid segments on its strobila with 20 to 30 uterine diverticula and 3 to 5 uterine pores ; and (iii) by the much larger average size of its testes.

Diagnosis of the new species *G. agraensis.*—Length of strobila 100 or more, maximum breadth 1·4. Proglottids number 125—150, very narrow in front; square about $\frac{1}{4}$th the length of the strobila from the scolex; progressively longer than broad subsequently; nearly half of them are ripe to gravid. Scolex on an average 0·3 long and 0·36 broad. Suckers nearly circular, with wide openings, diameter 0·125 ; fringed usually with a single row of spinelets. Rostellum with a single circle of about 31 hooklets or hooks of one kind, about 22 microns in total length. Neck short. Ovaries bilobed, antero-posteriorly elongated. Uterine diverticula 20—30, overlapping the ovary : uterine pores 3—5. Testes about 100, diameter 64·5—107·5 microns. Genital openings well in advance of the middle transverse margin, irregularly alternating ; cirrus sac and vaginal apertures vary as to which is anterior. Cirrus sac hardly extends medially to $\frac{1}{3}$rd across the segment; cirrus when everted very long and narrow, without spines. Habitat : intestine of Wallago attu Bleek., rivers and lakes of U. P., India.

NEW KEY * TO SPECIES OF THE *Genus Gangesia*

1.	Rostellar hooks indefinite (numerous), less than 10 μ long ... ... 2.	
	Rostellar hooks definite (below 60), more than 10 μ long ... ... 3.	
2.	Uterine diverticula 6—8, testes in one field	*G. osculata* (Goeze, 1782)
	Uterine diverticula about 24, testes in two or one (?) field	*G. malopteruri* (Fritsch, 1886) (Woodland, 1925)
3.	Testes in two lateral fields; vitellaria short, between ovary and genital pore ...	*G. pseudotropii* (Nov. Sp.)
	Testes in one field; vitellaria long, throughout proglottid length ... 4.	
4.	Rostellar hooks not uniform, of two sizes both less than 18 μ long ...	*G. macrones* (Woodland, 1924)
	Rostellar hooks uniform, of one size, more than 18 μ long ... ... 5.	
5.	Rostellar hooks about 22 μ long, in one row, about 30 in number; testes nearly 100 or more	*G. agraensis* (Nov. Sp.)
	Rostellar hooks about 40 μ long, in two rows, about 50 in number; testes nearly 200 or more	*G. bengalensis* (Southwell, 1913) (Verma, 1927)

* I regret I cannot insert my species in the key drawn up by Meggitt (1927) because (i) he does not appear to have taken notice of certain features in the anatomy of *G. malopteruri* described by Woodland (1925 b); (ii) the new species described here show great variation in the number of uterine diverticula, and (iii) the characteristics of *G. bengalensis* have been revised.

MONOZOA

Family AMPHILINIDAE

Amphilina paragonopora. Woodland, 1923.

Following are records of this species not hitherto published :

(I) *A New Host.*—Woodland (1923) described the species from the siluroid fishes, Macrones seenghala and Wallago attu. During the years 1926 and 1927 I had the opportunity of dissecting a number of another fish of the same family as those above-mentioned, namely, Bagarius yarrellii Sykes (=Pimelodus bagarius Ham. Buch.) which was found infected with this parasite as follows :—

Date.	Number of fishes examined.	Number of parasites obtained.
5th Sepr., 1926 ...	1	Nil
28th Sepr., 1926 ...	3	First : Nil Second : 1, orange coloured, 12 inches long. Third : 2, large as above.
15th Aug., 1927 ...	1	Nil
20th Sepr., 1927 ...	2	One in each.

All the above parasites were found in the body cavity of the host generally towards the anterior part of it, as noted by Woodland.

(II) *A New Region.*—As mentioned above all the specimens of *A. paragonopora* obtained by Woodland as well as by me in the new host were found to lie freely, or wound round the alimentary canal, in the body cavity. In one specimen of Macrones seenghala dissected in the M.Sc. Class, by one of our students on the 25th of August 1925, a

complete living example of this species was noticed inside the ovary of the fish. The ovary was carefully examined and found intact on all sides, therefore it cannot be said that the worm had lately bored into it from the body cavity. I think it developed from a young stage inside this organ which it had reached somehow. The length of this amphilina was about 8 inches and its colour creamy yellow.

In conclusion I wish to express my gratitude to Dr. D. R. Bhattacharya, D.Sc. (Paris), Ph.D. (Dublin), Head of the Department of Zoology, for various facilities so kindly provided by him in connection with this paper and certain suggestions concerning the same.

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Key to Lettering used in Figs. 1 to 48.

al.—anterior loculus of bothridium.
ao.—apical organ.
b.—bothridium.
bh.—bothridial hooks.
bl.—bladder or vesicle.
bm.—basement membrane.
c.—cirrus.
cao.—cavity of apical organ.
cl.—circular layer of muscles.
cs.—cirrus sac.
cu.—cuticle.
e.—eggs.
ec.—excretory canal.
ee.—egg-ejector or egg-swallower (schluckapparat).
fc.—fertilisation canal.
fp.—fibrous parenchyma.
ga.—genital aperture.
il.—internal layer of longitudinal muscles.
ip.—inner prong of bothridial hook.
is.—isthmus of ovary.
lmf.—longitudinal muscle fibres.
ln.—longitudinal muscles of neck.
ml.—median loculus of bothridium.
mp.—muscle pad.
n.—neck.
o.—ovary.
ol.—outer layer of longitudinal muscles.
op.—outer prong of bothridial hook.
ot.—ootype.
ov.—oviduct.
ovw.—oviducal wall showing large-nucleated muscles.
pl.—posterior loculus of bothridium.
r.—rostellum.
rh.—rostellar hooks.
s.—scolex or head.
sc.—nuclear layer of subcuticula.
sg.—shell gland.
sm.—sperm mass.
sp—spines or spinelets.
su.—sucker.
sv.—seminal vesicle.
syp.—spongy parenchyma.
t.—testes.
uc.—uterine canal.
ud.—uterine diverticula.
up.—uterine pore.
ut.—uterus.
v.—vagina.
vc.—vaginal duct or canal.
vd.—vas deferens.
vsr.—vaginal seminal receptacle.
vt.—vitellaria.
vtd.—vitelline duct.

In this connection I wish to convey my thanks to Mr. Ramapat Rai, artist of the Department, for the photomicrographs that are included in the above figures.

All drawings, unless mentioned as photomicrographs made with the camera lucida.

Explanation of Plate I.

(Figs. 1—5. *Acanthobothrium semnovesiculum* n. sp.)

Fig. 1—Entire specimen of *A. semnovesiculum* showing strobilisation and genital pores.

Fig. 2—Photomicrograph of longitudinal section through the head, bothridia and hooks. On the left one hook is cut transversely and shows the central cavity.

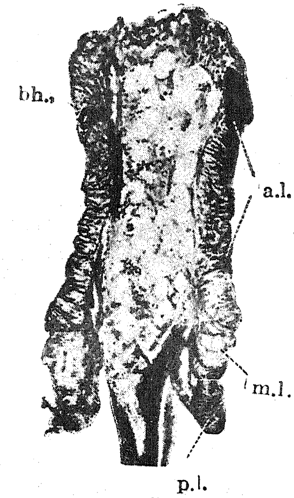
Fig. 3—Flattened mature proglottid from middle of strobila.

Fig. 4—Enlarged drawing of the female ducts in the inter-ovarial space.

Fig. 5—Photomicrograph of transverse section of a posterior segment, in front of the genital pore, indicating the large seminal vesicle full of sperms and the spongy parenchyma.

PLATE I

2



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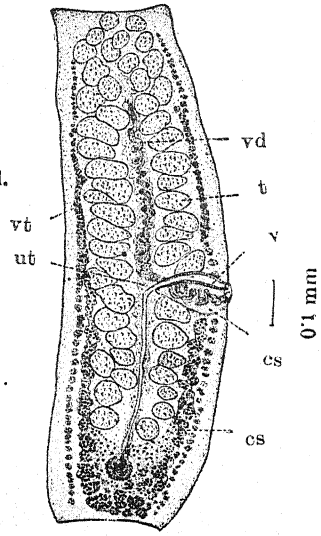

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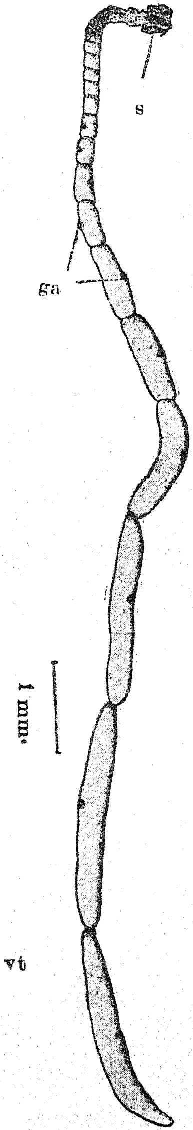

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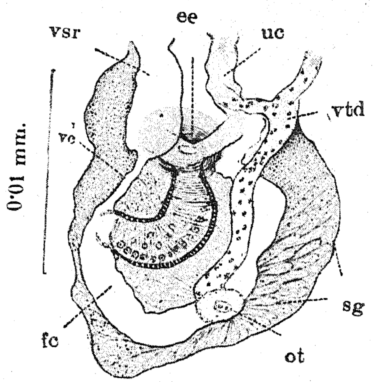

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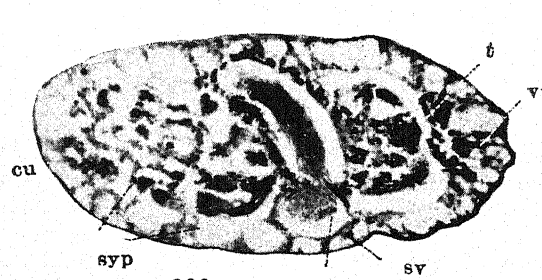

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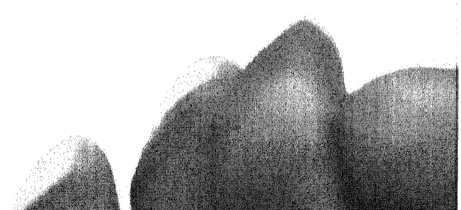

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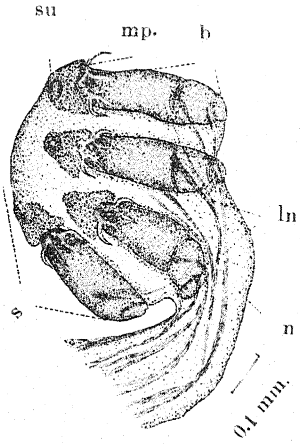

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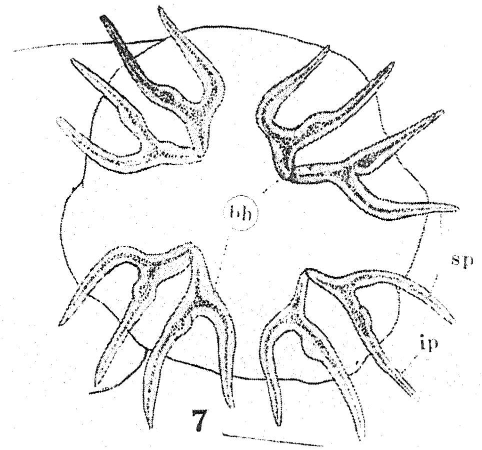

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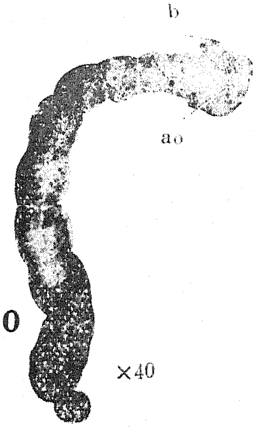

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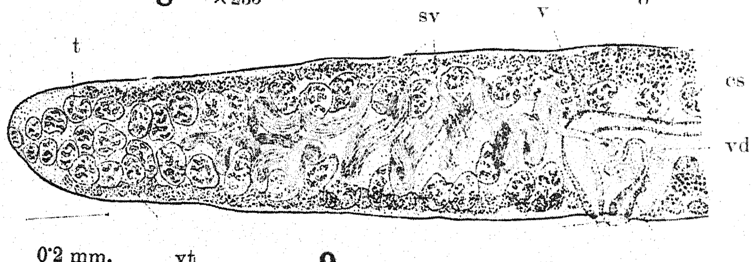

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EXPLANATION OF PLATE II.

(Figs. 6—9. *A. semnovesiculum*. Fig. 10. *Phyllobothriid* cestode gen. n. sp. *inq.*)

Fig. 6—Flattened scolex of *A. semnovesiculum* showing distinct suckers, muscle pads and bothridial loculi.

Fig. 7—Magnified surface view of scolex indicating the arrangement of bothridial hooks (inner prong longer than outer).

Fig. 8—Photomicrograph of horizontal section through the ovary; in the centre is visible the spherical egg-swallower and the oviducal bulb with thick muscular walls having large nuclei.

Fig. 9—Anterior half of a posterior segment; shows the characteristic seminal vesicle and the retracted spinose cirrus.

Fig. 10—Photomicrograph of a *Phyllobothriid* cestode, gen. and sp. *inq.*

EXPLANATION OF PLATE III.

(Figs. 11—18; *Ichthyotaenia vitellaris* n. sp.)

Fig. 11—Anterior end of *I. vitellaris*, somewhat flattened.

Fig. 12—Magnified view of the head region showing the cap-like apical organ, the suckers and the excretory canals.

Fig. 13—Maturing segment from the middle of the strobila; testes developed but ovary a narrow streak.

Fig. 14—Mature flattened proglottid.

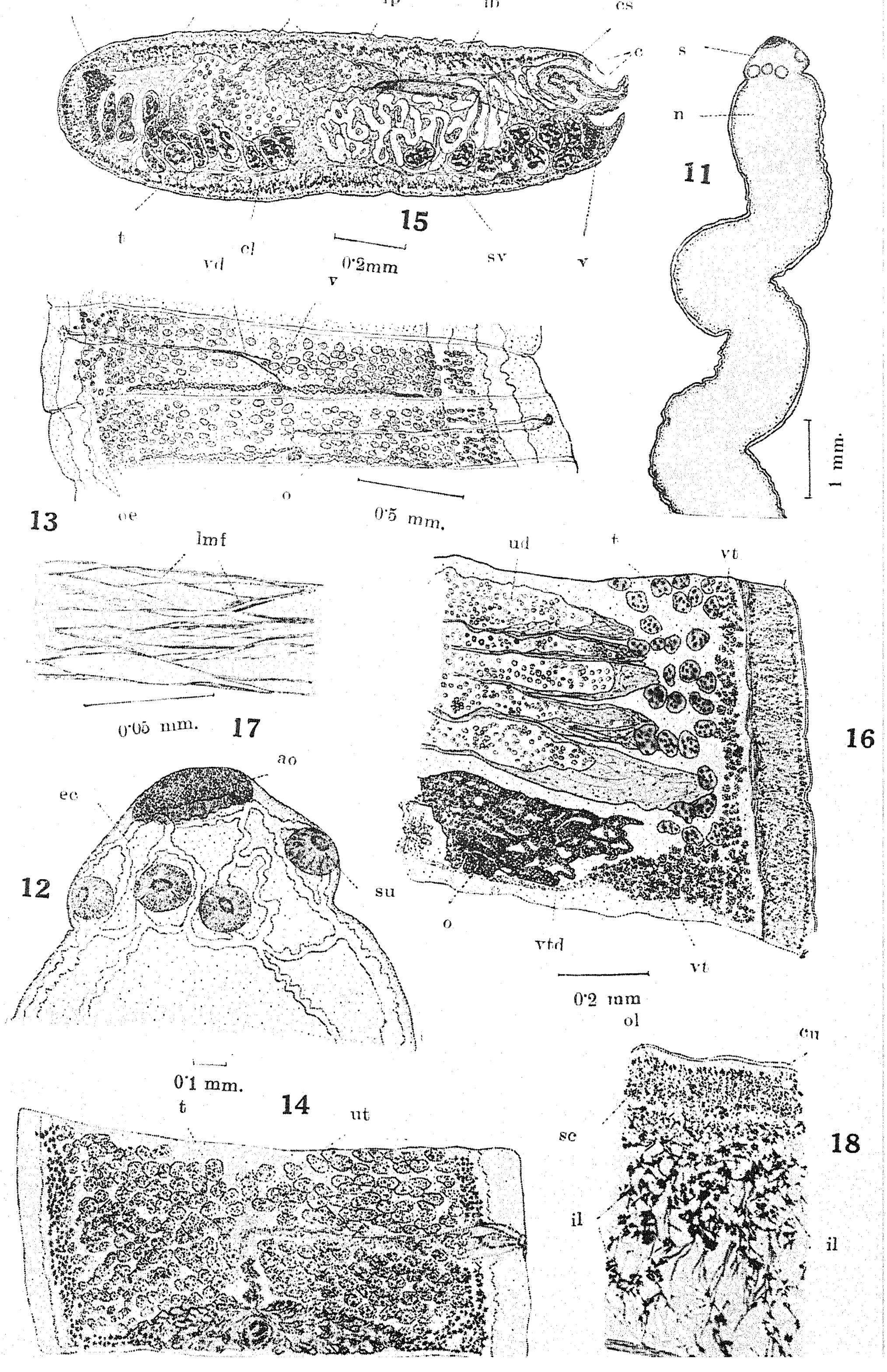
Fig. 15—Transverse section of a ripening segment through the cirrus sac.

Fig. 16—Right half of horizontal section of a ripe proglottid showing the uterine diverticula and L-shaped vitellaria.

Fig. 17—Horizontal section of body-wall through the internal layer of longitudinal muscles.

Fig. 18—Highly magnified view of transverse section passing through the body-wall.

PLATE III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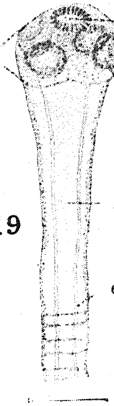

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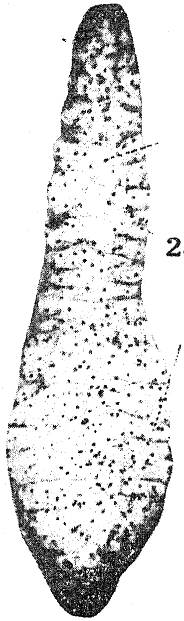

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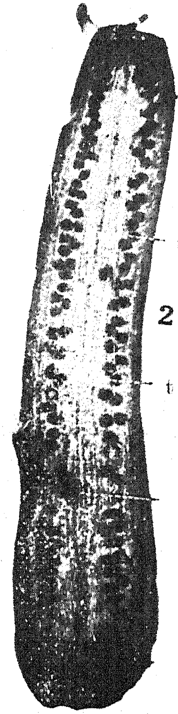

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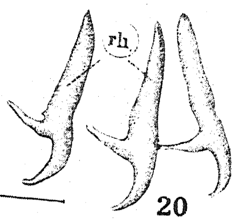

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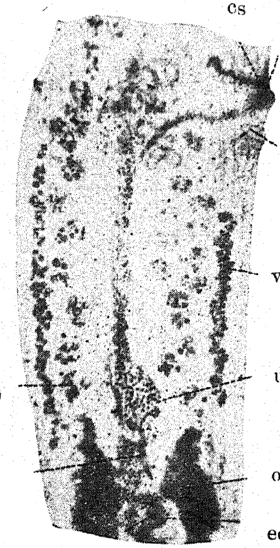

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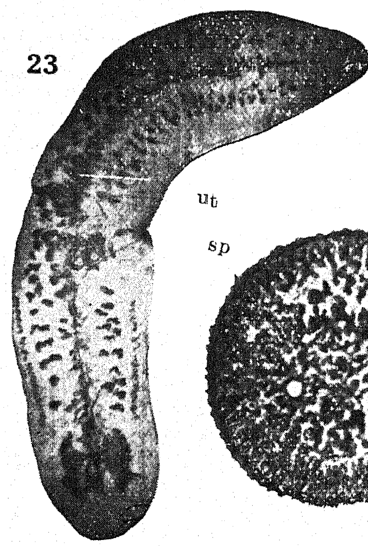

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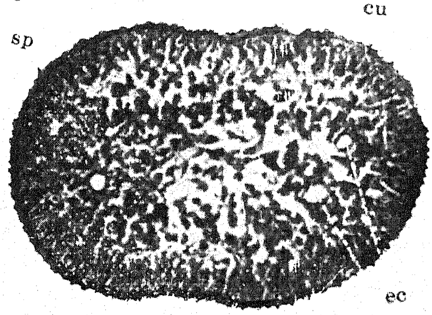

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EXPLANATION OF PLATE IV.

(Figs. 19—25; *Gangesia pseudotropii* n. sp.)

Fig. 19—Anterior end of an unpressed specimen of *G. pseudotropii*, cleared in creosote.

Fig. 20—Three hooks from the rostellum.

Fig. 21—Photomicrograph of a mature segment, feebly pressed; testes in two irregular rows; uterus a thin median tube.

Fig 22—Photomicrograph of a flattened proglottid, commencing to ripen; shows the characteristic vitellaria, the convoluted vas deferens (seminal vesicle) and the widened extremity of the uterus owing to reception of eggs.

Fig. 23—Photomicrograph of an isolated ripening segment showing the origin of the uterine diverticula. The globular egg-ejector is seen behind the isthmus in this as well as the previous figure.

Fig. 24—Photomicrograph of a detached gravid proglottid showing uterine diverticula with some eggs and the rupture of the ventral body-wall.

Fig. 25—Photomicrograph of a transverse section through the neck to show the cuticular spines, scattered bundles of longitudinal muscles and the excretory canals.

Explanation of Plate V.

(Figs. 26—31 ; *G. pseudotropii*—contd.).

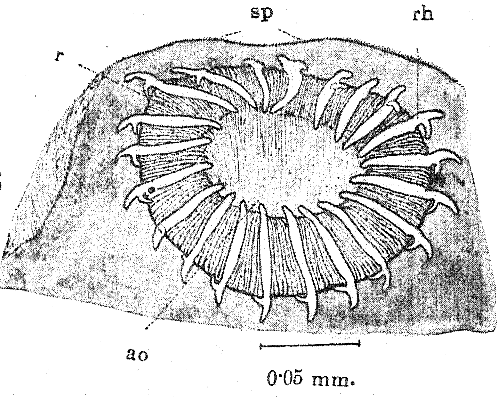
Fig. 26—Flattened rostellum with its muscular apical organ and crown of hooks.

Figs. 27-28—Longitudinal sections through the head end showing the structure of the apical organ and the suckers.

Fig. 29—Photomicrograph of transverse section through a mature proglottid.

Fig. 30—Photomicrograph of an advanced gravid proglottid to show the development of some eggs into the cysticercus stage.

Fig. 31—Photomicrograph of a flattened mount, in the region of shell gland, indicating the inter-relations of the female ducts.



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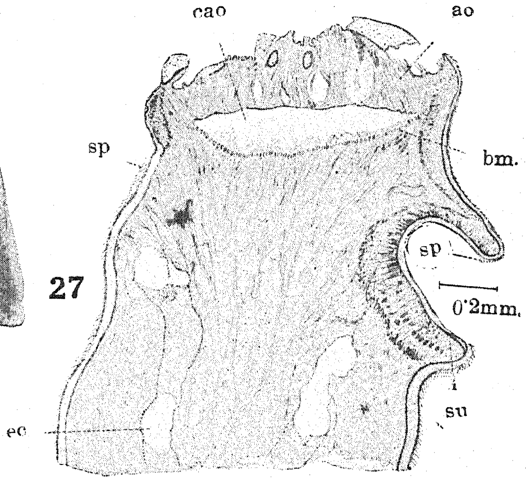

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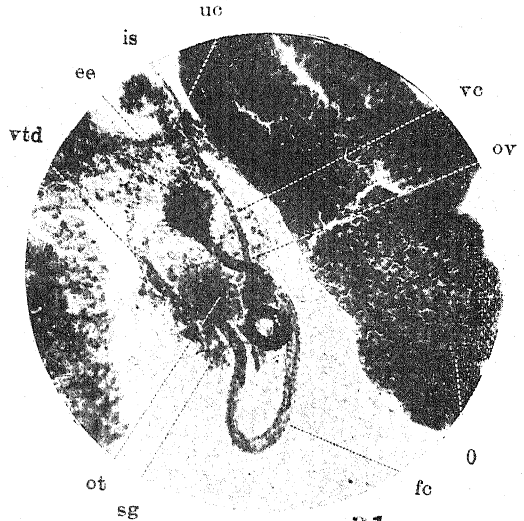

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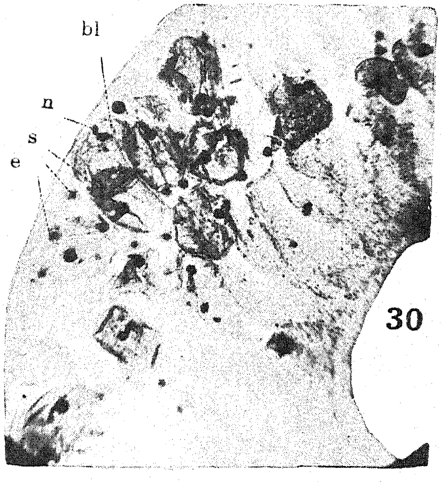

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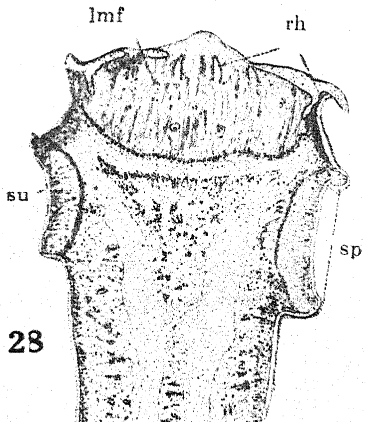

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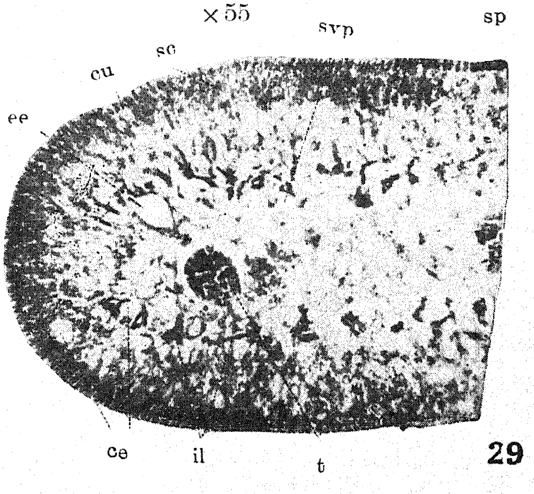

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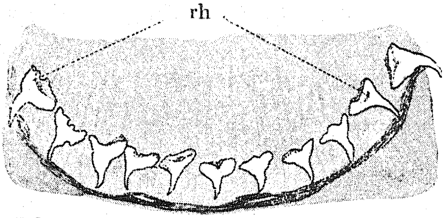

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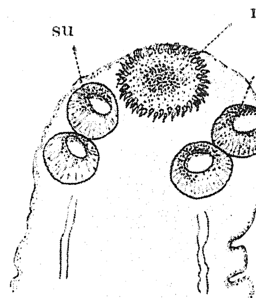

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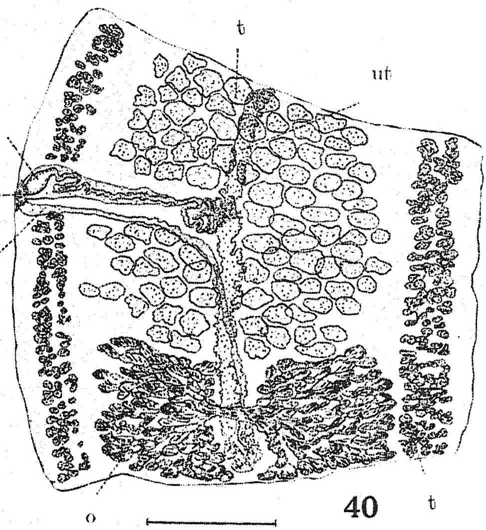

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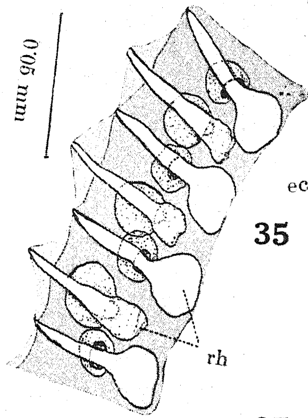

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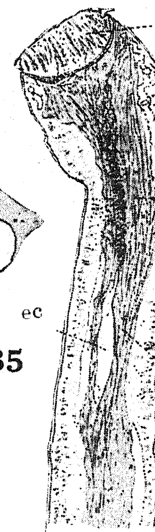

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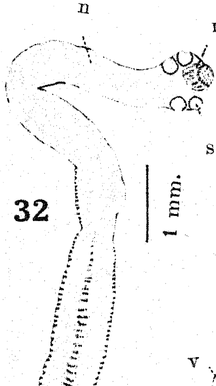

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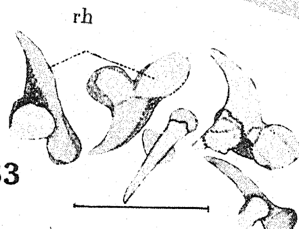

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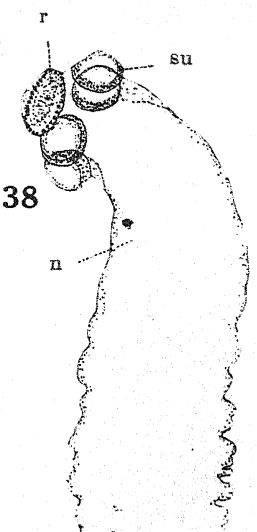

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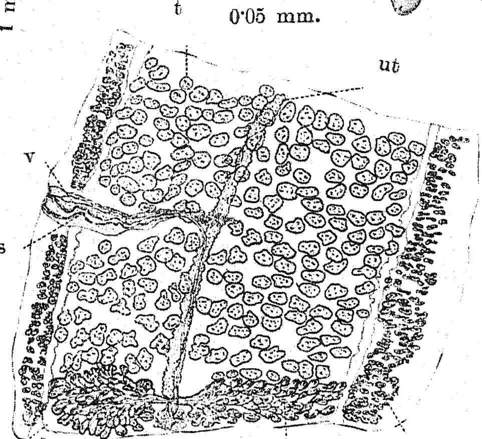


Explanation of Plate VI.

(Figs. 32—37; *Gangesia bengalensis* Southwell, and
Figs. 38—40; *G. agraensis* n. sp.)

Fig. 32—View of anterior end of a pressed specimen of *G. bengalensis.*

Fig. 33—Five spines in various positions.

Fig. 34—Magnified view of head end showing the rostellum with its hooks and suckers with narrow openings and spines.

Fig. 35—Enlarged drawing of part of rostellum showing the arrangement of hooks in two rows.

Fig. 36—Flattened mature proglottid; testes about 200.

Fig. 37—Longitudinal section through head and neck, not passing through the suckers.

Fig. 38—Anterior end of a flattened specimen of *G. agraensis:* suckers with wide openings.

Fig. 39—Part of a pressed rostellum showing the nature and arrangement of its hooks.

Fig. 40—Flattened mature proglottid; testes about 100.

Explanation of Plate VII.

(Figs. 41-42; *G. bengalensis*—contd.
Figs. 43—48; *G. agraensis*—contd.).

Fig. 41—Photomicrograph of part of scolex of *G. bengalensis* showing arrangement of rostellar hooks. The lower sucker to the right shows some spines.

Fig. 42—Photomicrograph of a mature flattened proglottid.

Fig. 43—Photomicrograph of part of scolex of *G. agraensis* indicating the number, shape and arrangement of rostellar hooks. Some of the spines on the edge of suckers are faintly seen.

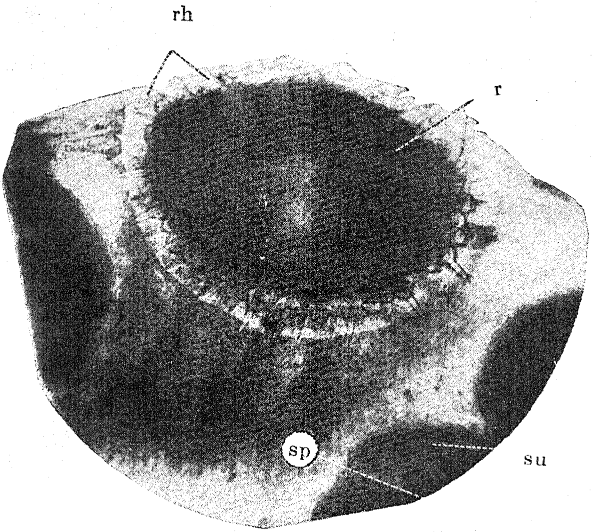
Fig. 44—Photomicrograph of a mature flattened segment.

Fig. 45—Photomicrograph of a ripe proglottid showing uterine diverticula with eggs; no uterine pores are visible.

Fig. 46—Photomicrograph of transverse section of an advanced ripe segment, in the region of the ovary; the wide ventral excretory vessels and the uterus sac forming the uterine pore is clearly seen.

Fig. 47—Photomicrograph of a gravid segment showing the five uterine pores; the diverticula have lost most of their eggs.

Fig. 48—Protruded cirrus.



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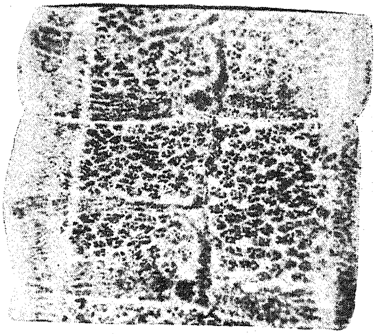

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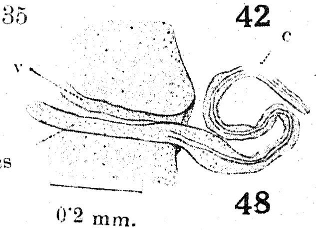

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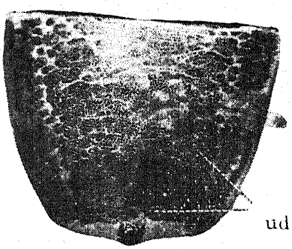

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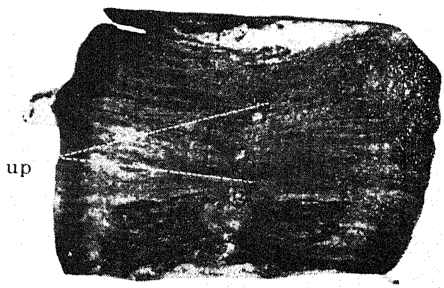

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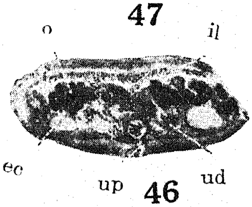

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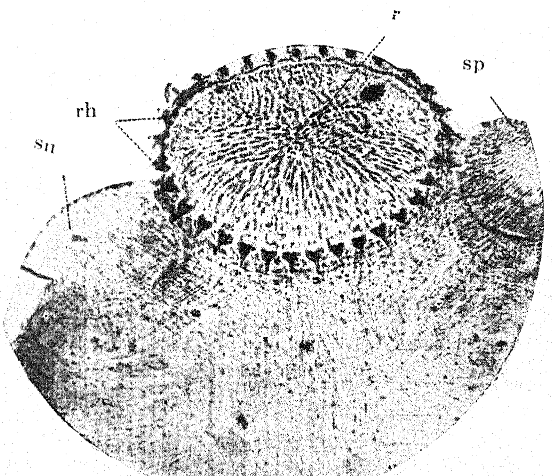

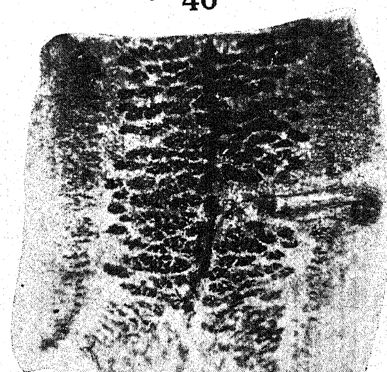

CYTOPLASMIC INCLUSIONS IN THE OOGENESIS OF PHERETIMA POSTHUMA.

BY

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CONTENTS.

1. INTRODUCTION.

The present piece of work was undertaken with a view to elucidate certain points regarding the behaviour of Golgi bodies, Mitochondria, Nucleolar Extrusions and Yolk during the Oogenesis of the common earthworm, Pheretima posthuma, found in abundance throughout the year in Northern India. This animal has another advantage in that the developmental stages can easily be traced out in the same ovarian tag, particularly in the breeding season. The ovary, however, does not furnish all the consecutive stages after the breeding season is over. Luckily, my work started just before the breeding season was over and I was able to collect ovaries from earthworms which were quite mature.

This work was suggested to me by Dr. D. R. Bhattacharya, because, of late, the oogenesis of Lumbricus has been the subject of discussion in the columns of Nature. Pheretima being an allied type, it was thought that it might help in throwing some light on the points under discussion in

Lumbricus. An attempt has been made in this paper to show that in Pheretima posthuma, the Oogenesis is simple and clear and that the results obtained are mostly in agreement with those obtained by Gatenby and Vishva Nath in Lumbricus (16) and therefore differ markedly from the observations of Harvey (18) on the latter animal. The present-day cytological technique is not so crude as Harvey would let us believe. Apart from classical methods there is a rapidly growing, fairly efficient, Intra Vitam technique which has enabled Parat (38) to revolutionise our ideas about Mitochondria and Golgi bodies. If both the classical methods and Intra Vitam examinations are carried out hand in hand by an experienced worker or by one under proper guidance, the Cytological details in the Oogenesis of many animals can be worked out with a certain degree of certainty.

I have pleasure in expressing my grateful thanks to Dr. D. R. Bhattacharya for suggesting this work to me and for valuable criticisms and advice during the progress of the work.

2. TECHNIQUE.

As already mentioned, the material used in this work was obtained from mature worms soon after they were captured in the fields. They were dissected alive and the following fixatives were used:—1. Da Fano. 2. Cajal. 3. Kopsch. 4. Ludford—Nassanow—Kolatchev. 5. Flemming without acetic acid. 6. Regaud. 7. Bouin. 8. Carnoy. The stains used include:—1. Heidenhain's Iron-alum Haematoxylin. 2. Gatenby's modification of Acid Fuchsin, Toluidin blue and Aurantia. 3. Ehrlich's Haematoxylin and Orange G. 4. Mann's Methyl blue Eosin. 5. Benda's Safranin and Light Green.

The Golgi bodies.—The Kopsch (21) method gave the best results. The entire ovaries were fixed in 2%

Osmic acid and kept in the dark for varying periods of time from 15 to 28 days. As a rule three weeks proved ideal. Curiously enough very satisfactory results were not obtained when the ovaries were first fixed in Osmo-sublimate and then in 2 % Osmic acid. The Golgi elements in Pheretima eggs are distinctly less osmiophile and sublimate seems in some way to inhibit proper impregnation. The next best fixation was obtained by Da Fano's Cobalt Nitrate method (9). I find if the quantity of Formalin is increased to more than 12 c. c. per 100 c. c. of water there is a general shrinkage of protoplasm, and the eggs become highly brittle. Cajal also gave satisfactory results. I have not had, however, much luck with Mann-Kopsch and other Golgi fixatives. I may mention here that I got unexpectedly good results by Gatenby's latest method of examining entire ovaries in Physiological salt solution to which a small quantity of Osmic Acid has been added (16). In less than quarter of an hour the Golgi spherules become beautifully impregnated and can be examined and their progress watched under the microscope. Parat's Neutral Red (38) method of INTRA VITAM and POST VITAM examination also proved very successful.

The Mitochondria.—Undoubtedly the best fixative for this purpose proved to be Flemming without Acetic acid. Champy-Kull was the next best particularly if the material is kept in 3 % Potassium bichromate for four days or more. Regaud's method proved to be a failure.

Nucleolus and Nucleolar Extrusions.—Bouin's fixative as well as that of Carnoy was used for detecting this type of cell inclusions. Sections of specimens fixed in these fluids were stained by Ehrlich's Haematoxylin and Mann's Methyl Blue Eosin.

Yolk and Fat.—Slides of material fixed by Osmic fixatives were treated for varying lengths of time in Turpentine. These were also stained by various combinations of stains

and the conclusions on the above were arrived at by a process of elimination.

3. THE GOLGI BODIES.

In the young oogonia the Golgi apparatus in Pheretima appears to be single and juxtanuclear (Fig. 1). The nucleus is large and excentric. In the earlier oocytes the Golgi elements are found to have increased in number (Fig. 2) and appear as a mass of very fine black dust over one side of the nucleus (Fig. 4). Unlike the results of Harvey on Lumbricus (18-19) who found the Golgi elements scattered in the cytoplasm from the very earliest stages and not condensed in the usual juxtanuclear position, my preparations (Kopsch) of Pheretima go clearly to show that the earliest Golgi elements have a tendency to remain focussed adjacent to nucleus (Fig. 2), in a particular denser area. In the later stages (Figs. 3 and 4) they begin to undergo scattering in the general cytoplasm. The Golgi elements in the older oocytes are situated in a haphazard manner in the general cytoplasm (Figs. 5 and 6), and are remarkably numerous in number. It is a noteworthy fact that they do not arrange themselves in the form of a ring either in a perinuclear position or as a cortical layer in the egg as is generally found to be the case in vertebrate eggs. It has also been noticed that sometimes one side of the egg is more heavily loaded with Golgi bodies than the other (Fig. 7). I am unable to account for this phenomenon except by the supposition that this particular side probably contained the original denser area which still functions in some way or other as the region of the focus of growth.

As regards the morphological nature of the Golgi elements, they appear as spherical bodies (Fig. 12) in Da Fano (9) preparations with a highly impregnated edge or rim. Structures which give an idea of dictyosomes are also present but it seems to me likely that they represent the

cut portions of the rim of a Golgi spherule. In Kopsch preparations the Golgi spherules appear as dark grey minute dots (Fig. 8). The Golgi bodies appear to be distinctly less osmiophile than is generally the case. This fact is corroborated by the observations of Gatenby and Vishva Nath (16) in Lumbricus where also a similar condition exists.

It may not be out of place here to give the results of a Post-Vitam examination of the ovaries. According to Gatenby's suggestion (16) I examined entire ovaries and placed them in a physiological salt solution to which some drops of 2% Osmic acid were added. Within five minutes of the removal of the ovary from the body of the animal, the Golgi bodies appeared to be impregnated and under the high power of the Microscope looked like small spherical bodies (Fig. 9) with a deeply impregnated greyish black and thick rim and a clear transparent core giving it very much the appearance of a Vacuome as suggested by Parat (37).

Entire ovaries were also examined by Parat's method in Neutral Red (38). A large number of spherical bodies were found in a fairly well-grown egg which took up the red colour within five minutes. These bodies appear to resemble the Vacuome described by Parat (38), by the same method. It seems probable that a large number of the spherical bodies with a black rim as demonstrated by Gatenby's method (16) are homologous with the spherical bodies or Vacuome so clearly brought into view by Parat's "Vital Coloration Method" (38). The noteworthy fact is that both by the wet methods and by the classical fixative methods the Golgi bodies appear spherical at least in the later stages of development.

The examination of a large number of entire ovaries by the wet method as suggested by Gatenby (16) revealed in some cases the presence of large yellowish-looking droplets in the stroma of the ovary. The droplets were also found in some cases on the surface of the ovary. Osmic acid

apparently does not blacken them and in spite of prolonged treatment in Turpentine they keep their yellowish colour. I am unable to explain the exact significance of these bodies, but I wonder if these are the bodies which have been mistaken by Harvey (18) for fat or yolk.

4. THE MITOCHONDRIA.

In the youngest oogonia which are extremely small cells, the nucleus practically occupies the whole area (Fig. 18 cyt.). There is only a thin small skin of cytoplasm surrounding the nucleus. In this earliest condition it has been found difficult to discover any granulations in the cytoplasm. In a slightly later stage, the nucleus begins to occupy the excentric positions and then granulations become more distinct (Fig. 14). The granular Mitochondria make their appearance in the form of a very small cap (Fig. 14) fitting closely to one side of the nucleus. The presence of the Mitochondrial cap can be demonstrated both by Flemming without Acetic acid and Champy-Kull methods. Later on the Mitochondrial cap begins to move around the nucleus though still persisting as a compact body on one side of the egg and finally acquires a perinuclear position (Figs. 15—18). The scattering of the Mitochondria in later stages in the oocytes is haphazard (Fig. 21). The juxtanuclear and perinuclear positions are lost and in a fairly developed egg Mitochondria is distributed throughout the cytoplasm (Fig. 22). The perinuclear and the peripheral zones of Mitochondria, as met with in many of the vertebrate eggs, are not noticeable here. A definite area exactly corresponding to the Yolk-nucleus of Balbiani is not met with unless the juxtanuclear concentration of Golgi bodies and Mitochondria is considered to be an equivalent stage.

The filamenter Mitochondria which Harvey (18) found and still believes to exist in Lumbricus (19) and which Gatenby refuted in a paper lately published (16) are

conspicuous by their absence in the case of Pheretima. Mitochondria invariably happen to be of a granular type (Fig. 23). Even after prolonged treatment with Potassium bichromate as suggested by Builliard (4) and Champy for the demonstration of filamenter Mitochondria, no trace of the latter could be found. It is quite possible that bad fixation of a bad material might have given Harvey the picture of Filamenter Mitochondria. Any way, the Mitochondria in Pheretima appear to be granular.

5. THE NUCLEOLUS AND THE NUCLEOLAR EXTRUSIONS.

From the earliest stages observable the original nucleolus seems to have disappeared and a large number of nucleoli arranged more or less in a peripheral manner inside the nucleus are visible (Fig. 14). The arrangement of the Nucleoli close beneath the nuclear membrane led me at first to suspect that Nucleolar Extrusions would be commonly found to occur in this animal. Various staining methods, however, proved that my suspicion was groundless. However, to make sure I examined material fixed in Bouin and Carnoy. I stained sections with Mann's Methyl-blue Eosin, Ehrlich's Haematoxylin and also Iron-Alum Haematoxylin. Although these methods have clearly demonstrated the phenomena of Nucleolar Extrusions in several animals as for example Saccocirrus by Gatenby (12), Lithobius by King and Nath (22—32), Testudo by Bhattacharya (1), etc., I have been unable to find any visible trace of Nucleolar Extrusions of any kind in Pheretima (Fig. 13). It is possible that exchange of nucleolar material between cytoplasm and the nucleus takes place in some soluble form which our present methods of technique are unable to demonstrate.

6. YOLK.

Neither *Intra Vitam* examination nor the usual fixative methods have revealed the presence of Yolk or Fat

in Pheretima posthuma in the eggs of the ovaries so far examined by me. I tried the usual Osmic acid method and treated slides with turpentine for varying lengths of time. I have tried various combinations of stains and other methods for the detection of the above-mentioned bodies. My experience leads me to think that there is no true Yolk or Neutral fat present in the eggs of Pheretima, at least in the stages so far examined by me.

7. DISCUSSION.

The Golgi body.—There is an undoubted concentration of Golgi bodies in the juxtanuclear position in the earliest eggs of Pheretima posthuma (Fig. 1). This concentrated area appears to function as a focus of growth and distribution (Fig. 2). It will be noticed that the general occurrence of Golgi bodies in the cytoplasm is not uniform and that the scattering of Golgi bodies always seems to take place from the original juxtanuclear Golgi area. This seems to be one evidence against the theory of their " de novo " origin. At the same time it is true that definite instances of Golgi division are hard to find. Whether the original Golgi network occurring in the earliest eggs inside a more or less dense area of cytoplasm is the result of an artifact formed by the action of the fixatives or is a true picture of a cellular phenomenon is yet little understood by us, and must still be admitted as a debatable point. Parat (37) is of opinion that the Golgi network or complex is the result of the action of fixatives. He says, that the Golgi bodies or Vacuome as he calls them, are spherical bodies with a definite shape. I must admit also that in my preparations either by the classical fixatives or by the vital methods, I have invariably found the Glogi bodies to be spherical in shape excepting in the very earliest stages where they appear to be in the form of a close network adjacent to the nucleus.

The Mitochondria.—Mitochondria in Pheretima can be seen distinctly in the later oogonial stages. Filamenter Mitochondria do not seem to be present in this animal (Fig. 23). Gatenby and Nath (16), however, definitely deny the presence of filamenter mitochondria in Lumbricus, and I am inclined to agree with them judging from my experience of Pheretima.

Nucleolar Extrusions and Yolk.—There seems to be little doubt that in Pheretima nucleolar extrusions do not occur. It is well known that in many cases where they occur they are either directly converted into Yolk or lost in the general cytoplasm and probably in some unknown way contribute their share in the formation of the ordinary proteid Yolk from the ground cytoplasm. In this case, however, there being no nucleolar extrusions, the question of the formation of nucleolar yolk does not arise. The Golgi bodies have been found in certain cases to acquire a swollen condition. These are naturally blackened by the Osmic methods, and may sometimes be mistaken for fatty Yolk or Neutral fat. Prolonged treatment in turpentine proves that they are simple Golgi bodies which have become a little inflated. I, however, labour under a difficulty that I have not been able to examine eggs at the zenith of the breeding season and therefore I feel reluctant in declaring definitely that the phenomenon of Yolk formation does not exist in the animal. Further work during the breeding season seems to be necessary on this point. The probability is, judging from my experience of the examination of various grades of eggs, that it will not differ very markedly from the condition found in Lumbricus by Gatenby and Nath. So far as Mitochondria are concerned, there is absolutely no doubt that they are granular and not filamenter and they keep their identity as such and do not show any sign of metamorphosis into Yolk. In Pheretima we can safely ignore the possibility of the formation of Yolk or

neutral fat from the ground cytoplasm as such formations are very easy to detect by the ordinary classical methods. On the whole it is my conviction that if Yolk is found at all to exist in this animal it will be fatty Yolk developed from swollen Golgi bodies. It is also possible that these swollen Golgi bodies which show a distinct osmiophility are degenerating Golgi elements as pointed out by Foot and Strobell (11).

8. SUMMARY.

Reviewing the whole work on Pheretima the following points may be summarised :—

1. A juxtanuclear area both in connection with Golgi bodies and Mitochondria exists.

2. The Mitochondria are clearly defined in the early oocytes and probably also in the oogonia.

3. The Mitochondrial cap spreads out first into a perinuclear position and then migrates away from the nuclear membrane and is more or less evenly distributed in the general cytoplasm.

4. The Golgi apparatus in the young oogonia is single and juxtanuclear. It breaks up and spreads out in the cytoplasm in the later stages in a haphazard manner. There is a definite concentration of these elements inside and around a central mass in the early stages, corresponding to the mitochondrial concentration.

5. There is no evidence of the Golgi bodies or Mitochondria arising " de novo ."

6. Neither Intra Vitam nor the usual fixative methods show the presence of either neutral fat or yolk.

7. The Golgi elements are less osmiophile than in those of many other animals.

8. The Golgi bodies in developed eggs are always spherical in shape.

9. The Mitochondria are not filamentar but granular.

10. There are no visible nucleolar extrusions into the cytoplasm.

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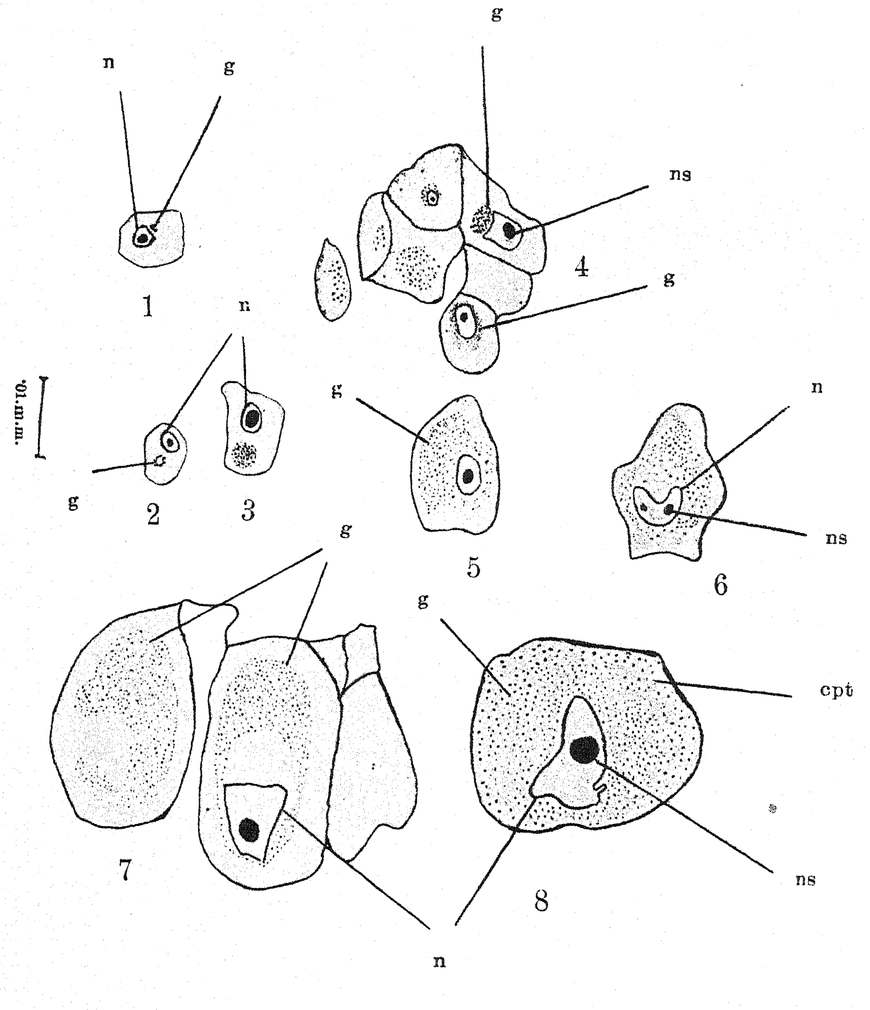
PLATE I.



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10. LETTERING AND EXPLANATION OF PLATES.

Lettering.

m—mitochondria.
mm—mitochondrial mass (the yolk nucleus of Calkins).
ml—mitochondrial layer.
n—nucleus.
nli—nucleoli.
ns—nucleolus.
nw—nucleus wall.
n s gr—nucleolar granules.
ot—ovarian tag.
cyt—oocyte.
g—golgi.
cypt—cytoplasm.
oyt—oogonium.

Explanation of Plate

Plate I.

Fig. 1—A young oogonium with a single juxtanuclear Golgi apparatus.

Figs. 2-3—Increase of Golgi elements to form a concentrated mass (Kopsch).

Fig. 4—Oocytes showing Golgi elements in various stages (Kopsch).

Figs. 5-6—Oocytes where the Golgi elements have begun to spread out to the periphery.

—Fairly mature oocytes in which Golgi elements have a tendency to become loaded more on one side of the nucleus than on the other. This depicts the original focus of growth of Golgi elements (Kopsch).

Fig. 8—Mature oocyte in which the Golgi elements lie scattered in the cytoplasm.

Plate II.

Fig. 9—Fresh mature oocyte in Osmic acid, showing Golgi Spherules with black rim and transparent core.

Fig. 10—Fresh mature oocyte in Neutral Red showing Golgi bodies.

Figs. 11-12—Two mature oocytes in which the Golgi bodies are distributed throughout the cytoplasm (Da Fano).

Fig. 13—Two mature oocytes showing no nucleolar extrusions (Bouin).

Plate III.

Fig. 14—Oogonium with a cap of Mitochondrial mass (Champy-Kull).

Fig. 15—Early oocytes with a cap of Mitochondrial mass over the nucleus (Champy-Kull).

Fig. 16—The binuclear oocyte with a Mitochondrial mass (F.W.A.)

Fig. 17—Oocyte with a Mitochondrial cap slightly spread out (F.W.A.).

Fig. 18—Oocyte with an ovarian tag containing several small oogonia. In this stage the Mitochondria have spread out (F.W.A.).

Fig. 18a—shows a stage slightly older (F.W.A.).

Fig. 19—Oocyte showing a peripheral Mitochondrial layer (Champy-Kull).

Figs. 20—23—Oocytes in which the Mitochondria are numerous and are distributed throughout the cytoplasm, with a tendency to form a peripheral layer.

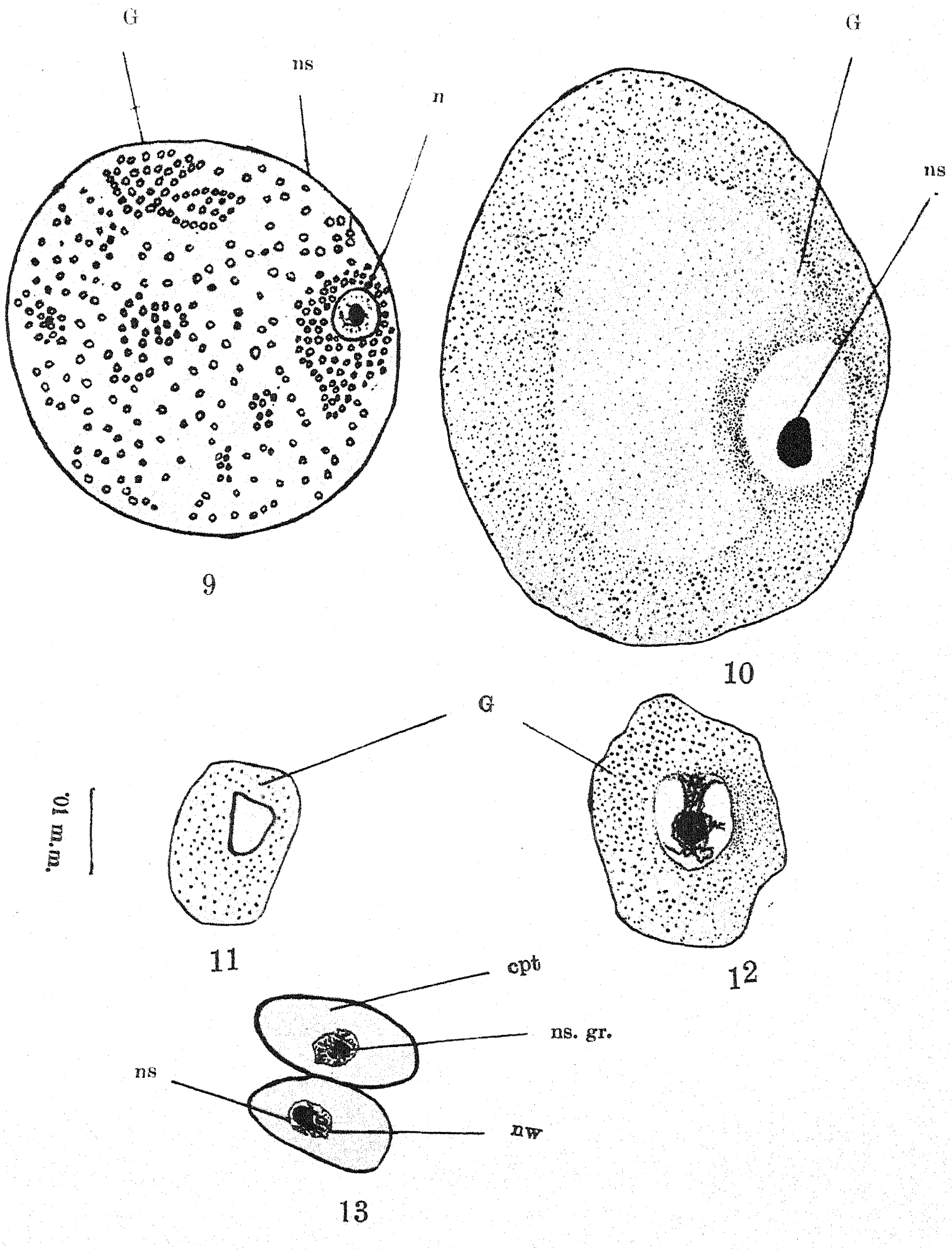
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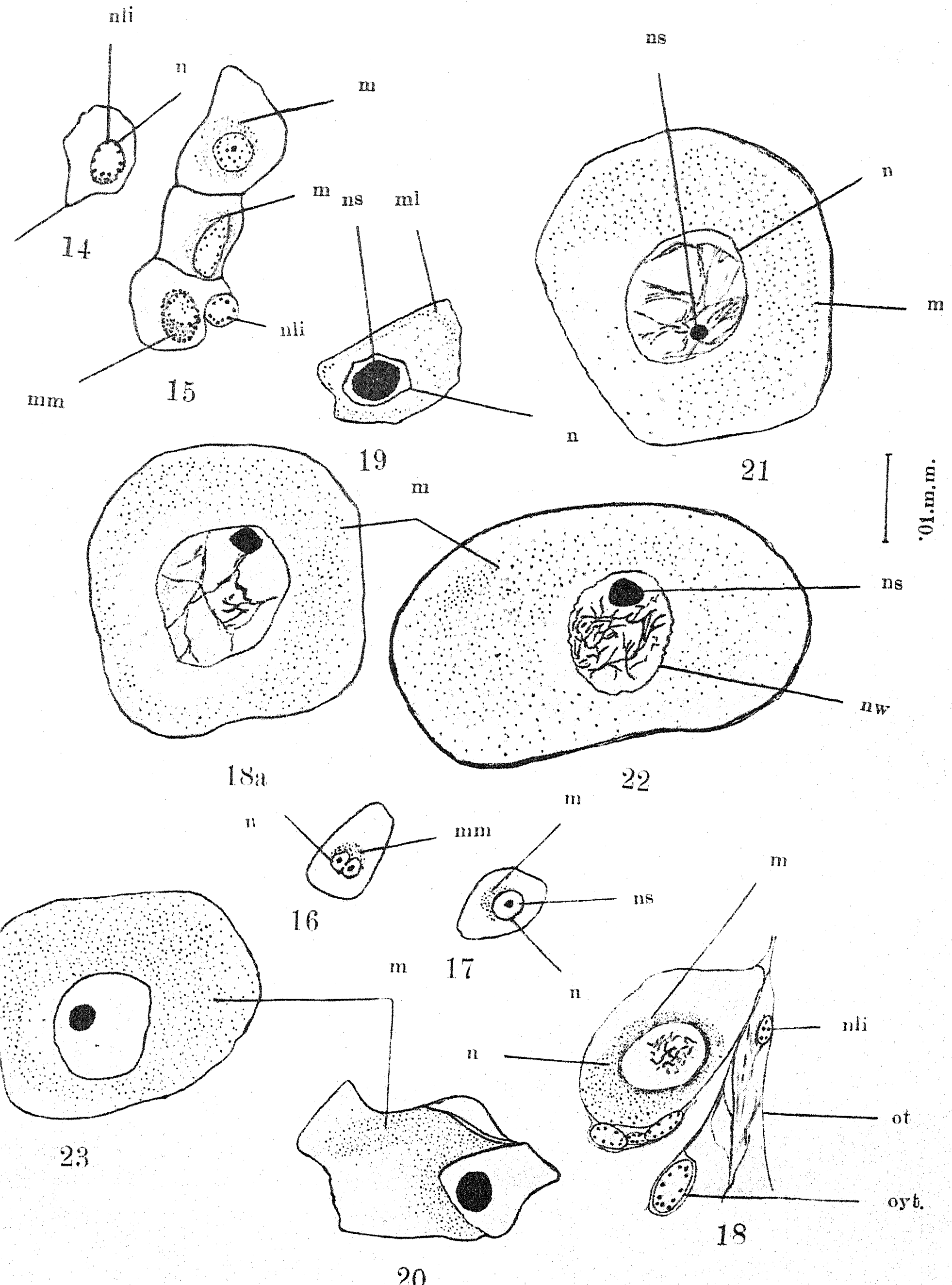
PLATE III.



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SECTION II.

BOTANY.

FUNGUS FLORA OF ALLAHABAD

Uromyces Andropogonis-annulati Syd. et Butl. nov. spec. on a new host, Andropogon pertusus Willd.

BY

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INTRODUCTION.

A collection of the fungi of Allahabad was commenced on the 15th of August, 1926. Since that time both parasitic and saprophytic fungi have been collected. Excursions were made regularly and every possible type of locality was inspected. Field crops were kept under constant observation and parks and even private gardens were visited. In all one hundred and seventy five (175) specimens were obtained up to the 15th of April, 1927. Of these, 50 were fully named, being run down to the genus and species, while in the case of another 50 only the genus was discovered.

Some of the parasites collected are serious fungoid pests and cause considerable damage to the crops concerned. Amongst these may be mentioned Puccinia graminis on wheat, Sclerospora graminicola on Bajra (Pennisetum typhoideum, Rich), Ustilago Hordei (Pers) Kell and Swin on Barley (Jau), Melampsora Lini on Linum usitatissimum (Ulsi), Tolyposporium Penicillariae on Bajra.

During the rains many Basidiomycetes (Toadstools, mushrooms, etc.), were available. Some of these, such

as the umbrella fungi (Agaricinae) and Scleroderma vulgare grew on the soil while others such as Auricularia sambicine, Hydnum, Sterium, Favolus, Schizophyllum commune and Fomes lucidus were found growing on dead wood or at the base of living trees.

This paper does not include an account of the local moulds and aquatic fungi which it was not possible to study in the time at my disposal.

Hand sections sufficed in most cases for a study of the fungi but in a few cases microtome sections were also prepared. Camera lucida drawings as well as free-hand drawings have been made, chiefly in the case of new species hitherto not described and also where something of special interest presented itself.

The work was carried out under the supervision and guidance of Dr. Julian H. Mitter, M.A., Ph.D. (London), F.L.S., Head of the Department, to whom I am greatly indebted for all his help and instruction. My best thanks are also due to Dr. William McRae, M.A., D.Sc., F.L.S., Imperial Mycologist, Pusa, for allowing me to work in his laboratory at Pusa and allowing me free access to his herbarium and library. I would also acknowledge my gratitude to Dr. McRae's assistants—Mr. S. N. Mitra and Babu R. R. Sen. I also received help from Dr. W. Dudgeon, Ph.D., and am thankful for the same.

Uromyces Andropogonis-annulati Syd. et Butl. nov. spec. on a new host, Andropogon pertusus Willd.

(With Plates I, II, and III.)

On November 29th, 1926, plants of *Andropogon pertusus Willd.* growing in the Botanical Garden of the Allahabad University were observed to be attacked by a fungus. Some of the plants were brought into the laboratory for

examination while the rest were left for the further growth and development of the fungus. From this time on, till the 10th of February, 1927, the fungus was kept under constant examination, fresh infected plants being examined on each occasion. The fungus infects both surfaces of the leaf. The shoot and the leaf-sheaths are unaffected. Purple-brown sori are present on upper and lower leaf surfaces, and contain two kinds of spores mixed together. There was no difficulty in recognizing the minutely spinous, pedicelled, one-celled, thin-walled Uredospores, but an attempt was made to find out of what type the other spores could be. These spores were also pedicelled but were smooth, one-celled and thick-walled. Some of these spores were put in water and some in 2% sugar solution, and moist chamber experiments were tried to induce them to germinate but without effect. They are teleutospores and will not germinate without a period of rest. Some infected bits of leaves were dehydrated and embedded in paraffin. Transverse sections were cut 5 μ thick and a careful study of the fungus was made. The description of the fungus is as follows :—

Teleuto-sori :—Amphigenis, solitary or aggregated, oblong or in a line, purple-brown; mixed with the Uredospores.

Uredospores :—Thin-walled, minutely spiny, globose, sub-globose or ovate; yellowish-brown in colour, 18—25·3$\mu \times$ 15·18—24 μ, Pedicel hyaline.

Teleutospores :—Thick-walled, one-celled, mostly globose, sub-globose or angular in shape, dark brown in colour, apex rounded, 25·3—34·04 $\mu \times$ 18·86—26·22 μ, Pedicel hyaline.

The above description agrees with that of *Uromyces Andropogonis-annulati Syd. et Butl. nov. spec.* which has been described by Sydow and Butler (1907) on *Andropogon annulatus.* The present fungus has recently been compared

with that on *Andropogon annulatus* at the Pusa Herbarium and was found to have the same structure but for minute differences in the size of the spores and the position of teleuto-sori which are amphygenis in the present case while hypophylis (on lower surface) in the case of the fungus described by Sydow and Butler.

SPORE MEASUREMENTS COMPARED.

	Uredospores.	Teleutospores.
Uromyces Andropogonis-annulati Syd. et Butl. nov. spec. on Andropogon annulatus, Pusa Herbarium.	18—25 × 15—24 μ	25—35 × 18—26 μ
Uromyces sp. on Andropogon pertusus Willd.—Allahabad.	18—25·3 × 15·18—24μ	25·3—34·04 × 18·86—26·22 μ

The slight differences in the size of Uredo and Teleutospores as shown in the table may be due to:—

(*a*) change of host

(*b*) change of environment

and therefore in my opinion negligible. Moreover, *Andropogon annulatus* and *Andropogon pertusus Willd.* are such closely allied plants growing close together in the same localities that it is most likely that *Andropogon pertusus Willd.* may also be subject to infection by *Uromyces Andropogonis annulati Syd. et Butl. nov. spec.* Thus I conclude that *Uromyces Andropogonis annulati Syd. et Butl. nov. spec.* also infects *Andropogon pertusus Willd.* on which it has not been previously recorded.

Andropogon pertusus Willd. grows profusely in Allahabad. As to its fodder value Watt says, "It is an excellent grass for grazing and stacking." Duthie says it is found in light soils and puts it among the first class fodder grasses. Rangachari remarks, "This is an excellent fodder grass and it grows quickly and stands cutting very well. Cattle eat this grass very well." [Burns, W. ; Kulkarni, L. B., etc., 1925.] The fungus causes considerable damage to this grass.

Table giving name of Fungus, its host and locality, etc.

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
Phycomycetes.				
1. Pseudoperonospora cubensis.	Lagenaria vulgaris.	Fields near Band-road.	10th November, 1927.	
2. Peronospora Trifoliorum De Bary.	Melilotus alba.	Alfred Park.	21st January, 1927.	
3. Peronospora parasitica (Pers) de By.	Brassica campestris.	Allahabad.	25th February, 1927.	
4. Peronospora vicias (Berk) de By.	Lathyrus sativus.	"	25th February, 1927.	
5. Sclerospora graminicola (Schroet) sacc.	Pennisetum typhoideum, Rich.	Fields near Munfordgunj.	7th November, 1926.	
Ascomycetes.				
1. Erysiphe Polygoni D. C. ...	Pisum sativum.	Bot. Gar., Alld. Uni.	28th February, 1926.	

2. Erysiphe sp. ...	Lagenaria vulgaris.	Fields near Band-road.	10th March, 1926.	
3. Dimerium sp. ...	Cordia myxa.	Alfred Park.	21st January, 1926.	Recorded on this host for the first time.
4. Asterina Lawsoniae P. Henn. et. E. Nym.	Lawsonia alba.	Mayo-road.	25th November, 1926.	
5. Capnodium brasiliense ...	Host unidentified.	1, Kucheri-road.	8th October, 1926.	
6. Xylaria sp. ...	Acacia sphaerocephala.	Bot. Gar., Alld. Uni.	21st September, 1926.	
7. Xylaria sp. ...	Host not known.	Shankergarh.	21st September, 1926.	
8. Daldinia concentrica ...	Tamarindus indicus.	Bank-road.	23rd September, 1926.	
9. Daldinia concentrica ...	Ficus Bengalensis	Allahabad.	15th December, 1926.	
10. Hypoxylon sp. ...	Citrus medica.	Bot. Gar., Alld. Uni.	17th September, 1926.	
11. Hypoxylon sp. ...	Dried branch of a tree.	Shankergarh.	21st September, 1926.	

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
12. Nectria sp. ...	Bambusa.	Allahabad.	29th September, 1926.	
13. Phyllachora spissa Syd. ...	Dalbergia sissoo.	Alfred Park.	25th February, 1927.	
14. Peziza vesiculosa ...	Cowdung.	Christian College grounds.	10th October, 1926.	
Uredinae.				
1. Uromyces Andropogonis-annulati Syd. et Butl.	Andropogon pertusus Willd.	Bot. Gar., Alld. Uni.	29th November, 1926.	Recorded on this host for the first time.
2. Melampsora Lini ...	Linum usitatissimum.	Bot. Gar., Alld. Uni.	14th February, 1927.	
3. Aecidium Amaryllidis ...	Crinum asiaticum.	Bank-road and Mayo-road.	11th September, 1926.	
4. Uredo Fici ...	Ficus carica.	Bot. Gar., Alld. Uni.	8th September, 1926.	

5. Puccinia triticina ...	Triticum vulgare.	Fields near Rajapur.	6th March, 1927.	
6. Puccinia glumarum ...	Triticum vulgare.	Fields near Bailey	6th March, 1927.	
7. Puccinia graminis ...	Triticum vulgare.	" "	12th March, 1927	Local name "*Giroi*"
8. Puccinia glumarum ...	Hordeum vulgare.	" "	6th March, 1927.	
9. Puccinia Cynodontis Desm.	Cynodon dactylon Pers.	Bot. Gar., Alld. Uni.	15th April, 1927.	
10. Ravenelia Breyniae Syd. ...	Breynia rhamnoides.	Alfred Park.	16th November, 1926.	
11. Ravenelia sessilis Berk ...	Albizzia Lebbek.	Mayo-road.	25th November, 1926.	
Ustilaginae.				
1. Ustilago Rabenhorstiana ...	Paspalum sanguinale.	Allahabad.	21st August, 1926.	
2. Ustilago Andropogonis-annulati Bref.	Andropogon Annulatus.	"	25th October, 1926.	
3. Ustilago sp. ...	Apluda varia.	Fields near Band-road.	9th November, 1926.	Recorded on Apluda varia for the first time.

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
4. Ustilago Scitaminea Syd. n. sp.	Saccharum officinarum.	Agricultural Farm, Naini.	15th January, 1927.	Dr. E. J. Butler, F. R. S., has changed the name from U. sacchari to U. Scitaminea Syd. n. sp.
5. Ustilago Hordei (Pers) Kell and Swin.	Hordeum vulgare.	Shivakuti and Rajapur.	27th January, 1927.	Local name "Kandu."
6. Ustilago Avenae (Pers) Jens.	Avenae sativa.	Karelabagh, Alld.	25th March, 1927.	
7. Ustilago Cynodontis P. Henn.	Cynodon dactylon Pers.	Bot. Gar., Alld. Uni.	10th April, 1927.	
8. Tolyposporium Penicillariae Bref.	Pennisetum typhoideum.	Fields near Georgetown.	15th October, 1926.	
Basidiomycetes.				
1. Auricularia sambucine ...	Acalypha sp.	Bot. Gar., Alld. Uni.	1st October, 1926.	A beautiful colony of more than

				200 individuals on a piece of stem 1 ft. long.
2. Auricularia sp. ...	Artocarpus Lakoocha.	Christian College grounds.	1st October, 1926.	Found in large numbers inside the rotten bark.
3. Clavaria sp. ...	Rotten wood.	Allahabad.	28th September, 1926.	
4. Stereum sp. ...	Ground.	Bot. Gar., Alld. Uni.	5th September, 1926.	
5. Hydnum sp. ...	Mangifera indica.	Shankergarh.	21st September, 1926.	
6. ,, ,, ...	Prunus communis.	Bot. Gar., Alld. Uni.	24th September, 1926.	
7. ,, ,, ...	Mimosa leucaena-glauca.	Bot. Gar., Alld. Uni.	24th September, 1926.	The parasite is very common and many species are found so that it presents a good field for research work.
8. Fomes lucidus ...	Not known.	Bot. Gar., Alld. Uni.	5th September, 1926.	
9. ,, sp. ...	Ficus religiosa.	Bot. Gar., Alld. Uni.	22nd Oct., 1926.	
10. ,, ,, ...	Cordia myxa.	Mayo-road.	22nd Oct., 1926.	
11. ,, ,, ...	Melia azadirachta.	Bank-road.	22nd Oct., 1926.	

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
4. Ustilago Scitaminea Syd. n. sp.	Saccharum officinarum.	Agricultural Farm, Naini.	15th January, 1927.	Dr. E. J. Butler, F. R. S., has changed the name from U. sacchari to U. Scitaminea Syd. n. sp.
5. Ustilago Hordei (Pers) Kell and Swin.	Hordeum vulgare.	Shivakuti and Rajapur.	27th January, 1927.	
6. Ustilago Avenae (Pers) Jens.	Avenae sativa.	Karelabagh, Alld.	25th March, 1927.	Local name "Kandu."
7. Ustilago Cynodontis P. Henn.	Cynodon dactylon Pers.	Bot. Gar., Alld. Uni.	10th April, 1927.	
8. Tolyposporium Penicillariae Bref.	Pennisetum typhoideum.	Fields near Georgetown.	15th October, 1926.	
Basidiomycetes.				
1. Auricularia sambucine ...	Acalypha sp.	Bot. Gar., Alld. Uni.	1st October, 1926.	A beautiful colony of more than

				200 individuals on a piece of stem 1 ft. long.
2. Auricularia sp. ...	Artocarpus Lakoocha.	Christian College grounds.	1st October, 1926.	Found in large numbers inside the rotten bark.
3. Clavaria sp. ...	Rotten wood.	Allahabad.	28th September, 1926.	
4. Stereum sp. ...	Ground.	Bot. Gar., Alld. Uni.	5th September, 1926.	
5. Hydnum sp. ...	Mangifera indica.	Shankergarh.	21st September, 1926.	
6. " " ...	Prunus communis.	Bot. Gar., Alld. Uni.	24th September, 1926.	
7. " " ...	Mimosa leucaena-glauca.	Bot. Gar., Alld. Uni.	24th September, 1926.	The parasite is very common and many species are found so that it presents a good field for research work.
8. Fomes lucidus ...	Not known.	Bot. Gar., Alld. Uni.	5th September, 1926.	
9. " sp. ...	Ficus religiosa.	Bot. Gar., Alld. Uni.	22nd Oct., 1926.	
10. " " ...	Cordia myxa.	Mayo-road.	22nd Oct., 1926.	
11. " " ...	Melia azadirachta.	Bank-road.	22nd Oct., 1926.	

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
12. Polystictus versicolor ...	Not known.	Shankergarh.	21st September, 1926.	
13. „ sp. ...	Mangifera indica.	„	21st September, 1926.	
14. „ „ ...	Rosa sp.	Bot. Gar., Alld. Uni.	25th September, 1926.	
15. „ „ ...	Zizyphus Jujuba.	Bank-road.	25th September, 1926.	
16. Lenzites Fr. ...	Decaying wood.	Jali Kothi, Colonelganj.	27th September, 1926.	
17. Favolus sp. ...	Tamarindus indicus.	Bank-road.	23rd September, 1926.	
18. „ „ ...	Melia azadirachta.	Chathem Lines.	25th September, 1926.	

19. Schizophyllum commune ...	Melia azadirachta.	Chathem Lines.	18th September, 1926.	
20. „ sp. ...	Zizyphus Jujuba.	„ „	23rd September, 1926.	Is of very common occurrence in Allahabad.
21. „ „ ...	Prunus communis	Bot. Gar., Alld. Uni.	24th September, 1926.	
22. „ „ ...	Mangifera indica.	Allahabad.	27th September, 1926.	
23. Agaricus sp. ...	Everywhere on the ground.	Allahabad.	August to November, 1926.	Many species, not identified.
24. Coprinus atramentarius ...	Everywhere on the ground.	„	28th September, 1926.	Popular name "*Ink-cap.*"
25. Coprinus comatus ...	Everywhere on the ground.	„	25th September, 1926.	Edible, locally called "*Khumbi.*"
26. Scleroderma vulgare ...	Ground.	Shankergarh.	21st September, 1926.	
Fungi Imperfecti.				
1. Diplodia sp. ...	Nelumbium speciosum.	Bot. Gar., Alld. Uni.	25th August, 1926.	

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
2. Diplodia sp. ...	Rosa sp.	Bot. Gar., Alld. Uni.	28th February, 1927.	
3. Colletotrichum sp. ...	Calotropis procera.	Bot. Gar., Alld. Uni.	26th August, 1926.	
4. Colletotrichum dracaenicole Sacc. et Trott.	Dracaena terminalis.	Bot. Gar. Alld. Uni.	29th August, 1926.	
5. Colletotrichum sp. ...	Bambusa.	Allahabad.	29th September, 1926.	
6. Colletotrichum gleosporoides.	Citrus medica.	"	25th February, 1927.	
7. Colletotrichum Lineola corda.	Sorghum vulgare.	"	10th October, 1926.	
8. Handersonina sacchari ...	Saccharum officinarum.	"	10th October, 1926.	
9. Cladosporium sp. ...	Saccharum officinarum.	Agricultural Farm, Naini.	15th January, 1927.	

10.	„ „ ...	Carica Papaya.	Bot. Gar., Alld. Uni.	17th January, 1927.	
11.	„ „ ...	Solanum melongena.	Bot. Gar., Alld. Uni.	28th October, 1926.	
12.	„ „ ...	Hibuscus esculentus.	Fields near Georgetown.	10th November, 1926.	
13.	Clasterosporium Mori ...	Morus alba.	Bot. Gar., Alld. Uni.	13th November, 1926.	
14.	„ sp. ...	Cordia myxa.	Alfred Park.	13th November, 1926.	
15.	Cercospora Menispermi. Ell et Holw.	Tinospora cordifolia.	Bot. Gar., Alld. Uni.	8th September, 1926.	
16.	Cercospora sp. ...	Hibiscus cannabinus.	Fields near Band-road.	9th November, 1926.	No species of Cercospora has yet been recorded on it.
17.	Cercospora Hibisci Tr. and Earle.	Hibiscus esculentus.	Fields near Band-road.	10th November, 1926.	
18.	Cercospora cruenta Sacc.	Phaseolus radiatus.	Fields near Bailey.	16th November, 1926.	

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
19. Cercospora Patouillardi Sacc. et D. Sacc.	Calotropis procera.	Bot. Gar., Alld. Uni.	25th November, 1926.	
20. Cercospora sp. ...	Cassia occidentalis.	Mayo-road.	25th November, 1926.	Cercospora is of very common occurrence.
21. Cercospora Fenilleauboisii Sacc.	Solanum nigrum.	Bot. Gar., Alld. Uni.	25th November, 1926.	
22. Cercospora sp. ...	Dalbergia sissoo.	Road-side Colonelganj.	16th December, 1926.	
23. ,, ,, ...	Crinum asiaticum.	Holland Hall compound.	26th December, 1926.	
24. Helminthosporium teres Sacc.	Hordeum vulgare.	Fields near Rajapur.	27th February, 1927.	
25. Helminthosporium sativum (P.) K. and B.	Triticum vulgare.	Fields near Rajapur.	27th February, 1927.	
26. Rhynchomyces ...	Graminae—stem.	Bot. Gar., Alld. Uni.	24th October, 1926.	

27.	Rhynchomyces ...	Luffa fruit.	Fields near Band-road.	16th December, 1926.
28.	Macrosporium sp. ...	Tinospora cordia-folia.	Bot. Gar., Alld. Uni.	18th January, 1927.
29.	„ „ ...	Cucurbita moscha-ta.	Fields near Band-road.	18th January, 1927.
30.	Alternaria solani ...	Solanum melonge-na.	Bot. Gar., Alld. Uni.	10th January, 1927.
31.	Fumago sp. ...	Citrus Aurantium fruits.	Bot. Gar., Alld. Uni.	13th December, 1926.
32.	Stilbum sp. ...	Bambusa.	Jalikothi, Colonel-ganj.	28th September, 1926.
33.	Stemmaria sp. ...	Tamarindus indi-cus.	Bank-road.	23rd September, 1926.
34.	Fusarium sp. ...	Cucumis sativa.	Fields near Band-road.	10th November, 1926.
35.	Fusarium sp. ...	Cucurbita mos-chata.	Fields near Band-road.	10th November, 1926.

Name of Fungus.	Habitat.	Locality.	Date of collection.	Remarks.
36. Fusarium vasinfectum ...	Cajanus indicus.	Agricultural farm, Naini.	15th January, 1927.	Dr. E. J. Butler, F. R. S., has recently changed the name from F. udum to F vas-infectum.

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DESCRIPTION OF PLATES—I, II, AND III.

Figures 1 and 2 are free-hand drawings, the other figures were all drawn with the camera lucida.

Lettering.

Epi, epidermis; G., germ-pore; L. S., lower surface of the leaf; M.T.S., mature teleutospore; N., nucleus; P., pedicel, S., Sorus; T.S. teleutospore; U. S., uredospore; Up., upper surface of the leaf; W., wall of the teleutospore.

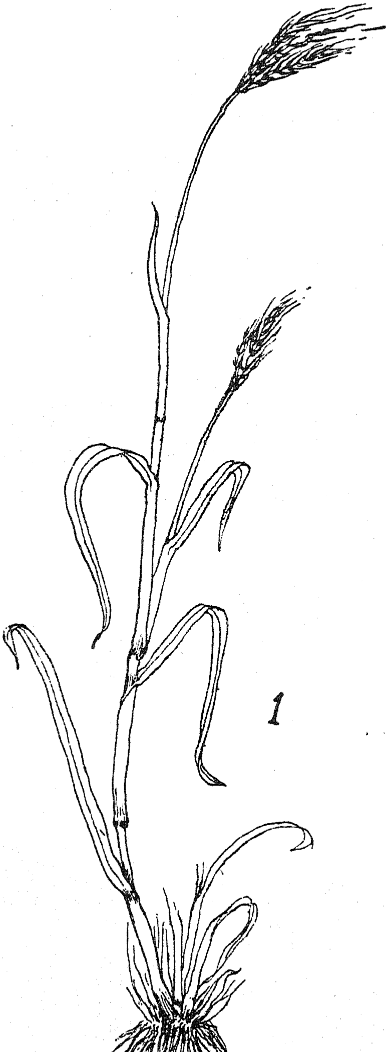
Plate I.

Fig. 1—Entire plant of Andropogon pertusus Willd., showing roots, stem, leaves and spikes. ¼ natural size.

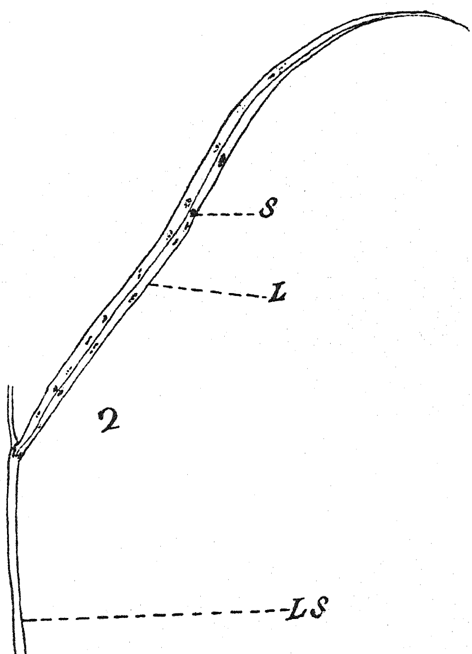
Fig. 2—Entire leaf showing the sori on its surface. Natural size.

Plate II.

Fig. 3—Uredospores and Teleutospores from the same sorus. X 310.



1



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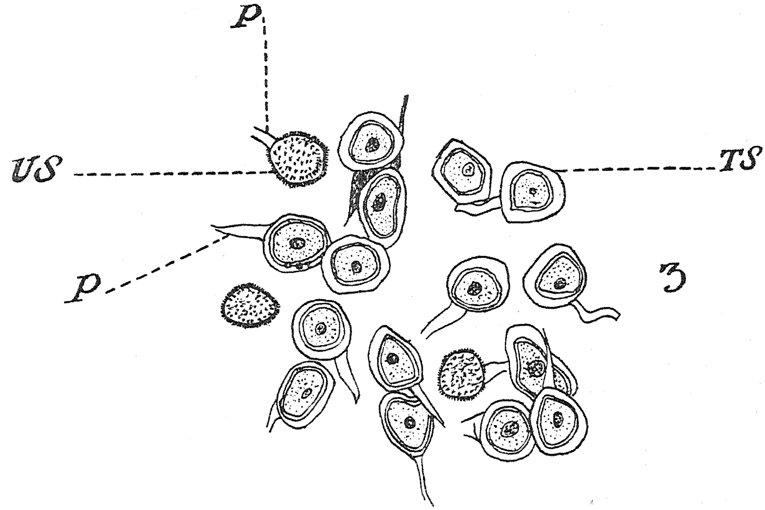
PL. II



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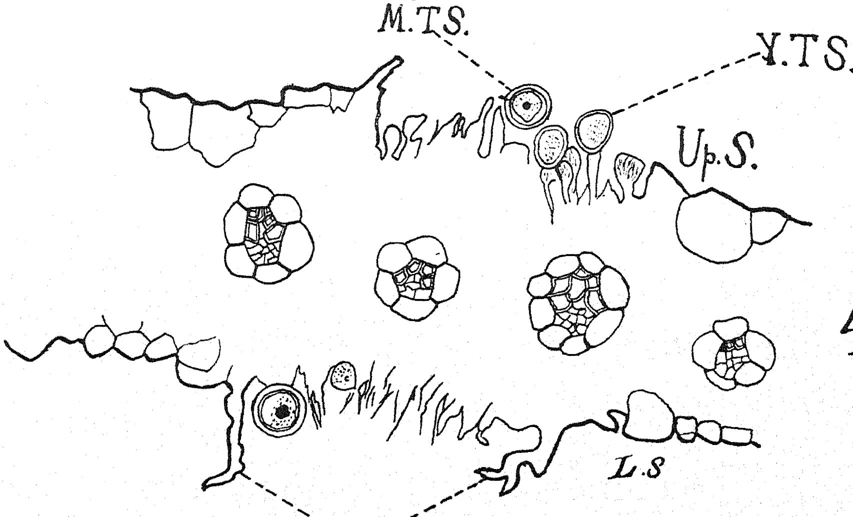

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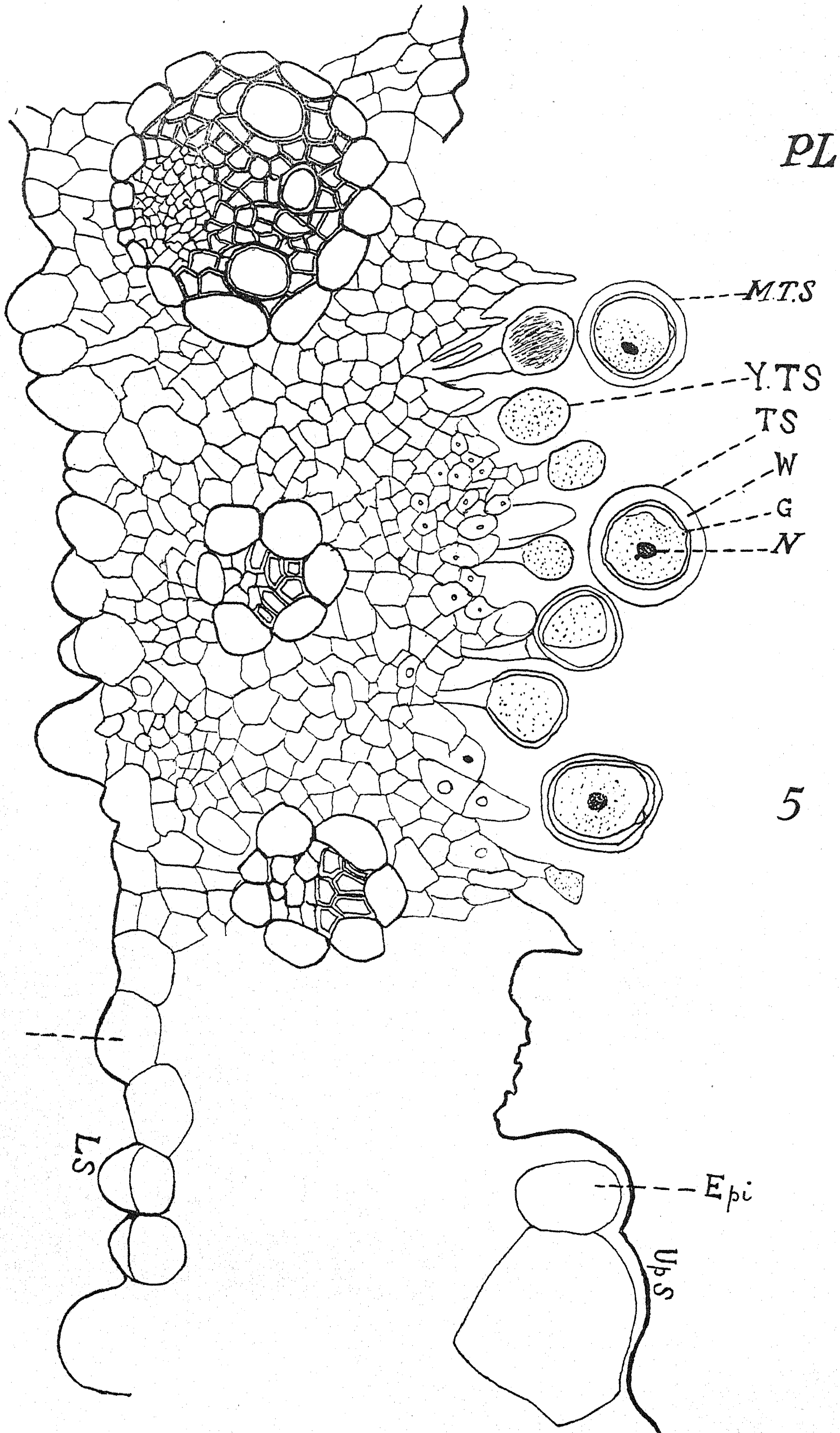

M.T.S
Y.TS
TS
W
G
N
5
Epi
LS
Epi
UpS

Fig. 4—Transverse section of a leaf showing sori on both the surfaces and the ruptured epidermis. X 310.

PLATE III.

Fig. 5—Transverse section of a leaf showing a sorus on the upper surface. The teleutospores are in various stages of development. X 620.

ABBREVIATIONS.

Bot. Gar. Alld. Uni.—Botanical Garden, Allahabad University.

SECTION III.

PHYSICS.

ACOUSTICS OF THE PIANOFORTE

BY

R. N. GHOSH, D.Sc.

In the acoustics of the pianoforte, there are three important factors upon which attention has been given by physicists, *viz.*—(1) the mechanism of the hammer, (2) the production of the tone quality in the struck string, and (3) the same in air. Helmholtz (1) first pointed out that the impact of the hammer is elastic lasting for a short time and imposing a pressure variation F $\sin\mu t$ upon the string. Kaufmann (2) however showed that the duration of impact is comparable to the period of vibration of the string, and that it depends upon the striking distance, and developed a simple formula for the calculation of the duration of impact in the case of an inelastic hammer when (1) the striking distance was small, also (2) when it was half the whole length of the string. Later on Profs. C. V. Raman (3) and B. N. Banerji showed that the duration of impact increases as the striking point moves further away from one end passing through small fluctuations. They developed a rigorous formula for the calculation of the duration of impact at any point of the string in the case of an inelastic hammer. Kaufmann's formula was recently extended by Mr. P. Das (4) for the same purpose. In 1924, the present author (5) showed that the elasticity of the actual hammer used in the pianoforte must be taken into consideration to calculate the duration of impact, and extended Kaufmann's formula to include the case of elastic hammer when the striking distance was small. The theory does not indicate the small

fluctuations mentioned before, and it does not hold good when the striking distance is large. From the experimental results it seems however that the simple formula can be used to calculate the duration of impact up to 1/6 without appreciable error. The formula can be put in the form

$$\frac{T}{\phi} = \frac{2}{\pi} \left[\frac{m}{M} \, \frac{l}{\alpha} \, \frac{1}{X} \right]^{\frac{1}{2}} \quad \text{approximately} \quad \ldots (1)$$

where m = mass of the string of length l.

M = effective mass of hammer.

α = striking distance.

$X = 1 + T_0/\mu\, \alpha$

T_0 = tension, μ = elasticity,

$$\frac{\text{period of vibration}}{\text{duration of contact}} = \frac{T}{\phi}$$

It may be pointed out that the above formula has been derived by the combination of the principles laid down by Helmholtz and Kaufmann. Experimental verification of the above formula has been made with different values of m/M, α/l and X, and the results agree with the theoretical value fairly.

Section 2.

THE TONE QUALITY OF THE STRUCK STRING.

The tone quality of an isolated struck string depends upon (1) the striking distance, (2) the hammer, (3) the tension and (4) the impinging velocity of the hammer. Experimental work in this connection is meagre except the recent work of Mr. W. H. George (6) and the pioneer work of Mr. S. K. Dutta (7) and the author's own experiments. Experiments (8) by keeping the velocity of impact constant, and varying the other quantities have shown (1) that the fundamental, and the octave have maximum amplitude when $\frac{T}{\phi} = 1$ or 2. They are minimum when $\frac{T}{\phi} = \cdot 5$ or $1 \cdot 5$. Other ratios beyond 2 were not investigated. This relation

has been found true when the striking distance is kept constant and the duration of impact is varied by changing the hammers. (Physical Review, December 1926, Vol. 27.)

It may however be pointed out that George's experimental results that the positions of the first maximum and the first minimum lie on hyperbolas when M/m is graphed against α/l as abscissa (p. 498, Phil. Mag., Vol. 51, 1925), agree with author's above conclusions. For equation (1) shows that the product of the two quantities is approximately constant. The tension affects the magnitude of the maximum amplitude, for instance, it has been found that the amplitude is reduced when the tension is increased. From the formula discussed in section (3) it will be observed that the amplitude is proportional to V/N where V_0 is the velocity of impact of the hammer, and N the frequency of the fundamental. Hence it is inversely proportional to the square root of tension. If the tension is kept constant, the maximum amplitude of the fundamental comes out the same when $\frac{T}{\phi} = 1$ or 2 for a given string.

Now the first condition for a good musical quality is that the first four partials must be strong. And this condition is fulfilled when $\frac{T}{\phi} = 1$ or 2. Hence the question that now arises is the choice between the two ratios. The effect on the musical quality when the first ratio is selected will be to increase the strength of the higher partials on account of reflections reaching the hammer from the further end. Thus the selection must be made such that $\frac{T}{\phi} = 2$. On looking back into equation (1) it will be found that this factor alone does not determine the absolute value of the mass of the hammer or the striking length. It will appear from the

discussion in section (3) that the consideration of the absolute magnitude of the fundamental at $\frac{T}{\phi} = 2$ does not fix the m/M or a/l. But there is the musical factor which determines the convergence of the partials, and this combined with the factor that $\frac{T}{\phi} = 2$, determine m/M and a/l (W. H. George and A. E. Beckett, Proc. Roy. Soc., Vol. 114, p. 134, 1927).

Section 3.

Calculation of Vibration Form.

The first thing to do is to obtain the pressure imposed upon the string by the hammer. It has been shown (9) that it is given by

$$p = \frac{V_0}{q} T_0 e^{\frac{-kt}{2}} \left\{ \frac{\operatorname{Sin} qt}{a} + \frac{R}{C} \cos(qt+\phi) \right\} \quad \dots \quad (2)$$

$$\tan\phi = \tfrac{1}{2} \left(\frac{m}{M} \frac{a}{l} \right)^{\frac{1}{2}} \qquad R^2 = q^2 + \frac{k^2}{4}$$

Graph of (2) is shown in Fig. (1)

At $t = 0$ when the impact begins, the pressure is $2V_0\rho C$ where ρ = mass of string per c.m. and C = velocity of transverse wave in the string. The pressure rising from this initial value attains a maximum value

$$p_m = \frac{V_0}{q} T_0 \, e^{-\frac{k\pi}{4q}} \left\{ \frac{1}{a} - \frac{k}{2C} \right\} \dots \quad (3)$$

$$\text{put } \chi = \frac{\pi}{2} \left(\frac{m}{M} \frac{a}{l} \right)^{\frac{1}{2}} \qquad n = S \, \pi C/l$$

and then becomes zero at the end of the impact. It will be found that p_m is a function of a. Corresponding

to the pressure given by (2) the generalised component of force is

$$\phi_s = \frac{V_0}{q} T_0 \, e^{-kt^1/2} \sin\left(\frac{S\pi a}{l}\right) R_2 \sin\left(qt^1 + \theta_2\right)$$

$$R_2 \sin\theta_2 = \frac{R}{C}\cos\phi, \; R_2\cos\theta_2 = \left(\frac{1}{a} - \frac{R}{C}\sin\phi\right)$$

$$\text{put } z = 2V_0 \, T_0 \, R_2 \sin\left(\frac{S\pi a}{l}\right) \Big/ m\, n \quad \ldots \quad (4)$$

and then the motion of the generalised co-ordinate ϕ_s is

given by $\dfrac{z}{q}\displaystyle\int_0^{\frac{\pi}{q}} \sin n(t-t^1) \, . \, e^{-kt^{1}/2} \sin(qt^1 + \theta_2)dt^1$

$$\phi_s = \frac{z}{2q}\left\{ e^{-\chi}\frac{[\sin(x_1 - n\pi/q)] + \sin x_1}{(q+n)} - \frac{k}{2}\,\frac{\cos x_2 + e^{-\chi}\cos(x_2 - n\pi/q)}{[(q-n)^2 + k^2/4]} \right.$$

$$\left. + \frac{[(q-n)\sin(x_1 - n\pi/q)]\, e^{-\chi} + \sin x_1}{[(q-n)^2 + k^2/4]} \right\}$$

$$x_1 = nt - \theta_2, \; x_2 = nt + \theta_2 \quad \ldots \quad \ldots \quad (5)$$

From (5) it is evident that the sth component vanishes if the striking point coincides with any of the nodal points of the same component.

When $n/q = m$, $m = 3, 5, 7$, etc.

$$\phi_s = \frac{zm^2}{2n^2}\left(\frac{1-e^{-\chi}}{(1-m)}\right)\left\{\frac{2\sin x_1}{(1+m)} - \frac{mk}{2n}\,\frac{\cos x_2}{(1-m)}\right\} \quad \ldots \quad (6)$$

$$m = 2, 4, 6, \text{ etc.}, \; \phi_s = \frac{zm^2}{2n^2}\left(\frac{1+e^{-\chi}}{(1-m)}\right)\left\{\frac{2\sin x_1}{(1+m)} - \frac{k\, m\cos x_2}{2\, n(1-m)}\right\} \quad (7)$$

$$m = 1, \phi = \frac{z\left(1-e^{-\chi}\right)}{2n^2}\left\{\frac{\sin x_1}{2} - \frac{2n}{k}\cos x_2 + \frac{k\cos x_1}{8n}\right\} \ldots \quad (8)$$

$$m = 4/3 \; \phi_s = \frac{zm^2}{2n^2}\,\frac{\left(1-e^{-\chi}\right)}{(1-m)}\left\{\frac{2\sin(x_1 - \pi/3)}{1+m} - \frac{km}{2n}\,\frac{\cos(x_2 - \pi/3)}{(1-m)}\right\} \quad (9)$$

From the formulæ (7) (8) and (9) it is found that the motion

is very feeble when the period of vibration of the sth component is 2/3, 2/5, etc., of the duration of impact. When however the period of vibration is 2/1, 2/2, 2/4, etc., of the duration of impact, the motion is finite. According to Helmholtz's theory, the motion entirely vanishes in the first case, but according to the law of pressure given above, it is not entirely evanescent, but it depends upon the damping factor K which in the case of constant tension is smaller the greater is the mass of the hammer. Hence in the higher octaves of the piano where the mass of the hammer is small, the motion under the case contemplated above is perceptible.

Thus we find that in the cases when $\frac{T}{\phi}=1$ or 2, both the fundamental and the octave are strong, whereas they are feeble when $\frac{T}{\phi}=\cdot 5$ or $1\cdot 5$ approximately, in agreement with experimental results.

From formulæ (7) and (8) we can calculate the vibration of the fundamental in particular cases of T/ϕ.

Let $\frac{m}{M_1 X}=x_1$,

$T/\phi=1$ and $x<1$

$$\phi_1=-\frac{V_0}{N}\frac{1}{3\pi}\left(\frac{1+e^{-\chi_1}}{x_1}\right)\sin\frac{4x_1}{\pi}.\sin n_1 t \quad \ldots \qquad (10)$$

$$\frac{T}{\phi}=2,\ x_2=\frac{m}{M_2 X}<1,\ \phi_1=-\frac{V_0}{N}\left(\frac{1-e^{-\chi_2/2}}{x_2^2}\right)\sin\frac{x_2}{\pi}\cos n_1 t \quad (11)$$

$$x_2>1,\ \phi_1=-\frac{2V_0}{\pi N}\cdot\sin\frac{x_2}{\pi}\left(\frac{1-e^{-\chi_2/2}}{x_2}\right)\sin n_1 t \quad \ldots \ (12)$$

$$N=C/2l$$

For a given value of x when $\frac{T}{\phi}$ is varied by changing the striking distance a, the amplitudes at $\frac{T}{\phi}=1$ and $\frac{T}{\phi}=2$

are found from (10) and (11) when $x<1$. The ratio is

$$\frac{1}{3\pi}\ \frac{\left(1+e^{-\chi_1}\right)\sin(4\,x_1/\pi)}{x_1}\cdot\frac{x_2^2}{\left(1-e^{-\chi_2/2}\right)\ \sin x_2/\pi}= \qquad Q$$

For a given value of $x<1$ this is found to be unity. This is in agreement with the results obtained experimentally, pages 877 and 885 (Phil. Mag., Vol. 50, 1926). For instance, let us put $x=1$, then the ratio is found very nearly equal to unity, and this is found to be the case according to the last table on p. 885. Similarly the results of Table I are also found to be true to the theory.

Amplitude N/V_0

TABLE I.

m/M	T/ϕ	A_2 Cal.	Aobs on different magnifications.
1	2	·123	3·20
3·7	2	·126	3·3
1	1	·140	3·7
·8	2	·130	23·5
·8	1	·180	20·0

Let A_1 denote the maximum amplitude when $\frac{T}{\phi}=1$ and A_2 when $\frac{T}{\phi}=2$.

From (1) we find A_1 is a complicated function of x. When A is plotted against different values of x, the value of A_1 is found to be continuously diminishing, and the curve does not show maxima. Similarly when A_2 is plotted against x_2 [$x_2<1$] no maxima is obtained. In the case

when $x>1$ a maxima is obtained for A_2 in the neighbourhood of $x=4$, giving $\frac{a}{l}=\frac{1}{2{\cdot}4}$. This value of the striking distance is of little importance, for the energy transfer from the hammer system to the string is greatly diminished, and reflections from the bridge increase the strength of high upper partials. The smaller the value of x the larger is the absolute magnitude of the maximum amplitude at $\frac{T}{\phi}=1$ or 2.

TABLE II $\frac{T}{\phi}=2$.

x_2	a/l	A cal.
·5	1/18	·141
1·0	1/9	·123
1·2	1/8	·120
1·3	1/7·9	·118
1·5	1/6	·106

Thus we find that the consideration of the biggest magnitude of the maximum amplitude at $\frac{T}{\phi}=2$ does not give a determinate value of x and therefore a/l also.

ELASTIC HAMMER.

The function of the elasticity of the hammer in pianoforte is not well understood. It is generally mentioned that the convergency of the partials is greatly increased by increasing the elasticity of the hammer felt. We have already shown that the duration of impact depends upon $x=m/MX$ and therefore the object will be achieved when $X=1$, and

a hard hammer M_1 of greater mass be substituted in place of the elastic hammer. Thus it is clear that the use of elastic hammer is not due to the increasing convergency of the partials alone. It will however be presently shown that the energy transfer from the hammer to the string is greater for any given value of x, the softer the hammer.

The loss of energy of the hammer after the impact is over is given by

$$E_1 = \tfrac{1}{2}MV_0^2\left(1 - e^{-X}\right) \quad \ldots \quad \ldots \quad (13)$$

The total energy of vibration of sth partial is given by

$$E_2 = \pi^2 n_1{}^2 s^2 A_s^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

Hence the fraction of energy that goes into the sth partial is equal to $E_2/E_1 = f_1$

$$f_1 = \frac{2\pi^2 \; n_1{}^2 s^2}{V_0^2(1 - e^{-X})} \frac{m}{M} \quad \ldots \quad \ldots \quad \ldots \quad (15)$$

A_s can be calculated from (7), (8) and (9). Taking A_s to be a function of x we can write (15)

$$f = \text{Const.}\; f\,(x).\; S^2 X \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

Thus for any given value of X the maximum fraction of energy transferred to any partial will be greater, the softer is the hammer. This gives the real explanation of the use of elastic hammer.

In the case of the Fundamental Table III shows the fraction of energy transmitted to it by the hammer for different values for X.

Fractional Energy of the Fundamental.

TABLE III $\frac{T}{\phi} = 2$.

x.	f.
·3	·026
·5	·024
·7	·025
·8	·025
·9	·023
1·0	·024
1·5	·021
2·0	·026

$$E_1 = \frac{\pi^2 m B_1{}^2 n_1{}^2}{4}, \quad B_1 = \frac{V_0}{N} \frac{\left(1 - e^{-\chi_2/2}\right) \sin \frac{x_2}{\pi}}{x^2_2}$$

$$f_1 = \frac{E_1 x}{\left(1 - e^{-\chi_2}\right)} \text{const.} \quad \ldots \quad (16)$$

In the case of the octave $\frac{T}{\phi} = 2$

$$E_2 = \pi^2 m B^2_2 n_1{}^2$$

$$B_2 = \frac{V_0}{N} \frac{1}{6\pi} \frac{\left(1 + e^{-\chi_2/2}\right) \sin \frac{2x_2}{\pi}}{x_2} \quad \ldots \quad (17)$$

$$f_2 = \frac{E_2 x}{\left(1 - e^{-\chi_2}\right)} \text{const.}$$

x	$1+e^{-x^2/2}$	Sin $2x/\pi$	$B_2 \div V_0/N$	f_2
·3	1·86	·2	·069	·021
·5	1·78	·295	·059	·017
·7	1·71	·44	·060	·020
·8	1·67	·49	·056	·020
1·0	1·60	·61	·94	·018
1·2	1·55	·72	·051	·018
·9	1·64	·56	·057	·0195

From these tables we find that the energy of the fundamental and octave is large at $x = \cdot 8$. This gives $\frac{a}{l} = \frac{1}{12}$. This is very far from the actual choice in the striking point. Probably at $\frac{1}{9}$ the musical quality is considerably improved without entirely great diminution of the energy that is transmitted to the string by the hammer.

Coupled Oscillation of Bridge and String.

The theory that has been presented in the preceding section holds in the case of an ideal string fixed at both ends. In the actual case, however, one end is fixed and the other end passes over a flat bridge fixed to the sound board. The same bridge extends over the sound board and other strings also pass over the bridge. The vibration of the string is communicated to the sound board through the bridge, but in doing so reactions of other strings on the bridge are brought in, and hence the oscillation of the latter is greatly damped.

The vibration of the string will also be damped on account of the drain of energy (10) from it to produce

vibrations of the sound board. The greater the vibration of the sound, the greater will be the drain, and heavy will be the damping of the string. Let us assume that the vibration of the string is given by

$$y = \mathrm{F}\, e^{(ip+q)ct} \left\{ e^{(ip+q)x} - e^{-(ip+q)x} \right\} \quad \ldots \quad (18)$$

where $x=0$ fixed end, and $x=l$ is the end connected to the bridge, and qc is the damping coefficient. Let us further assume that the vibrations of the sound board do not depart to a large extent from the normal modes on account of damping, and that they are given by

$$a_r \ddot{\psi}_r + b_r \dot{\psi}_r + g_r^2 \psi_r = f(t) \quad \ldots \quad \ldots \quad (19)$$

where $f(t)$ is the force exerted at the end $x=l$, and ψ_r is the normal co-ordinate.

$$\text{Now } f(t) = -\mathrm{T}_0 \left(\frac{dy}{dx} \right) . r, \quad \text{when } x = l$$

$$= -2\,\mathrm{T}_0\, \mathrm{F}.\, r.\, e^{(ip+q)ct} .(ip+q). \left\{ \cos pl + iql \sin pl \right\} \quad (20)$$

From (19) and (20) we get ψ_r

$$\psi_r = - \frac{2\,\mathrm{T}_0\, \mathrm{F}.\, r.\, e^{qct}. \cos pl}{a_r \quad \mathrm{D}_r^2} \left[\mathrm{P}_r \cos nt + \mathrm{Q}_r \sin nt \right] \quad (21)$$

$\mathrm{P}_r = [\mathrm{A}_r\, q + 2n\, \mathrm{B}_r\, p],\ \mathrm{Q}_r = (2n\, \mathrm{B}_r - \mathrm{A}_r\, p)$

$\mathrm{A}_r = \{ (m^2 - n^2) + 2kqc + q^2c^2 \}$

$\mathrm{B}_r = (k+qc),\ \mathrm{D}_r^2 = \mathrm{A}_r^2 + 4n^2\, \mathrm{B}_r^2$

$\dfrac{b_r}{a_r} = 2k,\ pc = n \quad \dfrac{g_r^2}{a_r} = m^2$

$r =$ resolution factor of the force.

The yielding the bridge must be equal to the transverse displacement of the string at the end $x=l$. Hence

$$\Sigma\, r.\, \psi_r = \mathrm{F}\, e^{(ip+q)ct} \left[e^{(ip+q)l} - e^{-(ip+q)l} \right] \quad (22)$$

Equating the coefficients of cos nt and sin nt we get the following relations :

$$ql = -T_0 \left[\frac{r_1^2}{a_1} \frac{P_1}{D_1^2} + \frac{r_2^2 P_2}{a_2 D_2^2} + \cdots \right] \quad \ldots (23)$$

$$\tan pl = T_0 \left[\frac{r_1^2}{a_1} \frac{Q_1}{D_1^2} + \frac{r_2^2 Q_2}{a_2 D_2^2} + \cdots \right] \quad \ldots (24)$$

The motion of the rth co-ordinate is shown by (21). It is found that the damping of the sound board and bridge is the same as the string, as is expected to be the case. Further the resultant vibration will be very large when D_r^2 is small; this is found to be the case when $m=n$. Under these circumstances, there will be heavy drain of energy from the string, and the damping will be very great. That such is the case is found from (23), which becomes very large when any one of the denominators becomes small. The free periods of vibration, when coupled to the bridge, are given by (24). Generally the effect of vibration of the sound board upon the free period of the string is small, except when any of the normal nodes coincides with that of the string.

Further it will be observed that the damping coefficient of the string affects the free period even when the squarres of that quantity are neglected in comparison to larger quantities. The first effect of the coupled oscillation of the bridge is to diminish the frequency of free vibration of the string. The diminution is larger the smaller the inertia of the bridge, vanishing in the case of infinite inertia of the bridge.

We find from equations (23) and (24) that the damping coefficient of the string will be different for different fre-

quencies. Hence some vibrations will die out more rapidly than others. But the most important result is the change in the quality of the note as the vibrations die away. The different components have different rates of decay, hence the quality undergoes a gradual change as the vibration of the struck string dies out. The effect is most marked when any of the normal modes of the bridge coincides with that of the string. That this takes place has been observed by Prof. Miller in his book on "Science of Musical Notes" (page 208).

Section 5.

Free Vibrations of the Sound Board.

The exact theory of vibrations of a clamped square plate is very complicated, but an approximate calculation can be made for the frequency of oscillations by the method of prescribed vibrations satisfying the conditions at the boundary. At the boundary of a clamped plate the displacement and tangent must be zero. Let us assume that the displacement w is given by $w = k(c^2 - x^2)^2 (c^2 - y^2)^2$ where the origin of co-ordinates is the centre of the plate. The total kinetic energy is given by

$$T = \int\int \tfrac{1}{2}\rho_1 \, 2h \left(\frac{dw}{dt}\right)^2 dx dy$$

$2h$ the thickness of plate and ρ_1, its density

$$= \rho_1 h \left(\frac{256}{315}\right)^2 c^{18} \left(\frac{dk}{dt}\right)^2 \dots \qquad \dots \quad (25)$$

$2\,c =$ side of the plate.

In the same way the potential energy

$$V = \frac{Eh^3}{3(1-\mu^2)} \left(\frac{256}{35}\right)^2 k^2 c^{14} \quad \dots \qquad \dots \quad (26)$$

If $w = A \cos pt_1$ then

$$p/2\pi = 1{\cdot}64\, v_1 . \frac{2h}{(2c)^2}$$

$$v_1^2 = E/\rho_1\ (1-\mu^2)$$

If $2c = 100$, $v_1 = 3{\cdot}85 \times 10^5$ cm., $2h = {\cdot}5$ cm.

$$\frac{p}{2\pi} = 32.$$

Thus we find that the fundamental vibration of the sound board has a very low frequency, other modes of vibration can be calculated by the above method but the numerical calculation is very tedious. The damping of the sound board due to radiations of sound is very small compared to the damping on account of reactions of the strings upon the vibrations of the bridge. Proceeding on the same lines as Prof. Lamb (10), we can obtain a superior limit of the loss of energy by radiations.

The integral of the normal velocity over the surface of the plate is

$$\int\int \frac{dk}{dt} dxdy\ (c^2-x^2)^2(c^2-y^2)^2$$

$$= \left(\frac{dk}{dt}\right) \left(\frac{16}{15}\right)^2 c^{10}$$

The effect at a distance is, therefore, that of a simple source of strength $2\left(\frac{dk}{dt}\right)\left(\frac{16}{15}\right)^2 c^{10}$

The mean rate at which energy is carried outwards by the hemispherical waves, is, therefore, $\frac{p^2\rho}{16\pi c_2}\left[2Ap\left(\frac{16}{15}\right)^2 c^{10}\right]^2$

where $k = A \sin pt$.

ρ = density of air.

c_2 = velocity of sound in air.

The mean energy of the plate, being twice the mean kinetic energy is $2\rho_1 hA^2p^2 \left(\frac{256}{315}\right)^2 c^{18}$

Equating the rate of decay of the energy to the emission we find

$$\frac{dA}{dt} = -\beta A, \ \beta = \frac{p^2 \ (2c)^2}{2h} \ \frac{\rho}{\rho_1} \ \frac{1}{c_2} \times \cdot 039$$

For the plate of the particular dimensions mentioned above, and for a frequency of vibrations 312

$$\beta = 2 \cdot 5 \times 10^{-2}$$

In the actual case, the damping due to radiations will be much smaller than the above value, since there will be many nodal lines, and different parts of the board will be moving in different phases. Hence the damping due to radiations will be less than the above value

$$\beta < 2 \cdot 5 \times 10^{-2}$$

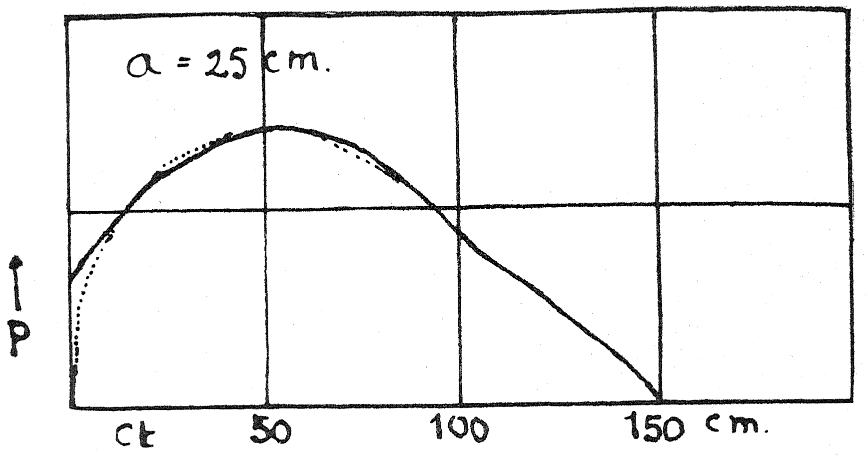
Damping due to radiations is, therefore, very much smaller than that due to reactions of the strings and friction which is of the order 10^1.

REFERENCES.

(1) Sensation of Tone, p. 380.
(2) Ann d. Physik., Vol. 54, p. 675 (1895).
(3) Proc. Roy. Soc., Vol. 97, p. 99.
(4) Proc. Ind. Assn., Vol. 7, p. 13.
(5) Phil. Mag., Vol. 47, p. 1142 (1924). Also Proc. Ind. Assn., Vol. 9, p. 193 (1925).
(6) Phil. Mag., Vol. 51, p. 498 (1925).
(7) Proc. Ind. Assn., Vol. 8, p. 107 (1923).
(8) Phil. Mag., Vol. 50, p. 875 (1926).
(9) Phil. Mag., Vol. 49, p. 121 (1925).
(10) Proc. Roy. Soc., Vol. 98, p. 205 (1921).

Fig. (2) shows the wave at the striking point, and Fig. (3) the same at 4 cms. from the striking point. The wave shows that the string attains the velocity of the hammer at the beginning of impact, starting suddenly from rest. This is clearly shown in Fig. (3). Figs. (2) and (3) were both obtained from felt hammers.

FIG 1.

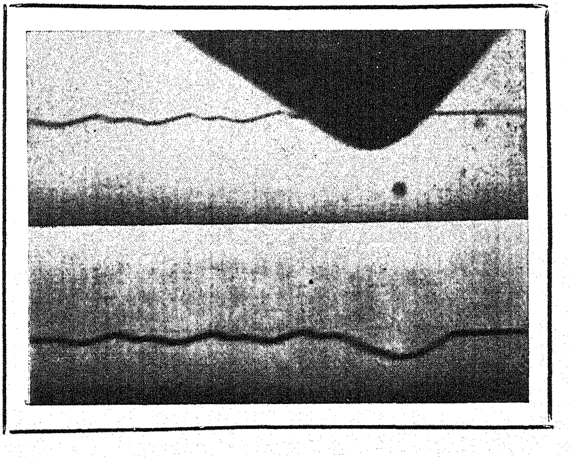


[PRESSURE AND DISTANCE CURVE.]

Fig. (1) shows that the pressure is finite at $t=0$ for a felt hammer. *Vide* Equation (2).

FIG. 2.

FIG. 3.



Figs. (2) and (3) show the wave form during impact of a felt hammer. Fig. (2) represents the wave at the striking point, and Fig. (3) the same at 4 cm. from the striking point. The inclination of the wave form shows finite velocity of the string at $t=0$.

ON THE ARC SPECTRUM OF BISMUTH[1]

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SUMMARY.

The arc spectrum of Bismuth has been investigated in the heavy arc, and under-water spark, and the lines remeasured between λ 1900 and λ 3550. A discussion of the structure of the spectrum of Bismuth from the standpoint of the theories of complicated spectra is given. It is shown that in Bismuth, owing to its large atomic number terms arising from the same level are separated by widely different levels, and this renders the interpretation of the spectrum rather difficult. A large number of new lines has been obtained and a number of important lines has been carefully remeasured. The new lines include some predicted by Thorsen.

The arc spectrum of Bismuth is interesting from more than one point of view. Thirty years ago Kayser[2] and Runge tried to discover regularities and found that the spectrum consisted of groups of lines having the separations 11418, 4019, and 6223. The last group consisted in some cases of close doublets with the separation 1·91. Ruark, Mohler, Foote, and Chenault[3] investigated the excitation and the ionisation potential of the element by the electron bombardment method. They arranged the lines in a number of fundamental levels (denoted by $3d_2$, $3d_1^B$, $3d_1^A$, etc.)

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[1] Published in Phil Mag., Vol. IV, Oct. 1927.
[2] Kayser : Handbuch der Spectroscopie 2, p. 576.
[3] Ruark, Mohler, Foote and Chenault : Sc. Pap. of the Bureau of Standards, 19, 463, 1923-24.

and sub-levels denoted by Greek letters $\alpha, \beta, \gamma,$ etc. They added with some hesitation two levels 1s. and β, to those given by Kayser and Runge. While this paper was being written there appeared a paper by Thorsen (Ziet. f. Phy. Band 40), who tried to discover Rydberg sequence in the spectrum of Bismuth.

On the experimental side Offermann[1] gave an accurate measurement of wave lengths from λ 6134 to λ 2061. Randall[2] has explored the infra-red region from λ 9600 to λ 22000 by means of a grating, a thermopile and a Paschen Galvanometer. Walters[3] has measured the wavelengths in the arc spectrum within the region λ 5600 to λ 9600 by means of photography. Takamine and Nitta have measured the spectrum on the short wavelength side of λ 1900, while Bloch[4] and McLennan[5] in the Schumann region down to λ 1400. Zeeman effect has been studied by Purvis,[6] but the data does not seem to be reliable.

The spectrum of Bismuth has been studied in this Laboratory by Dr. N. K. Sur in the furnace and under-water spark. The results were not published in the expectation of a more extensive investigation. I took up the work started by Dr. Sur and have investigated the 20 amp. arc spectrum.

The region λ 4800 to λ 3500 was photographed by means of a 5 ft. Rowland Grating (dispersion 11·12 A° to a mm.), from λ 3550 to 2170 was investigated on Quartz spectrograph E I (Adam Hilger), kindly lent to us by Dr. N. R. Dhar of the Chemistry Department, and from λ 2170 to λ 1900 on the above-mentioned grating and also on a

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[1] Offermann, Kayser and Konen : Handbuch der Spectroscopie, Vol. 7, p. 104.
[2] Randall, Astro. Jour., 34,1,1911.
[3] Walters, Sc. Pap. Bureau of Stand., Vol. 17, p. 168, 1922.
[4] L. and E. Bloch, C. R., 170, 320 and 171, 709 (1920).
[5] McLennan and Young, P. R. S. (Lond.), 98, 95, 1920.
[6] Purvis, Pros. Camb. Phil. Soc., 14, 216, 1907.

quartz spectrograph. Comparison spectra of Iron was taken up to 2300, that of copper arc from λ 2300 to λ 2170 and that of silver spark down to λ 1900.

My measurements substantially agree with those of Offermann; the differences between the two greater than ·02A° have been noted down. Offermann's data is used between 3500—4800, since my measurements of the plates in this region cannot be accurate in the second decimal place, because of the small dispersion in the first order of the grating. The lines marked by T in this region are new lines and there is a possible mistake of not more than ·08A°.

Between λ 2170 and λ 1900, my measurements differ considerably from those given by Eder and Valenta, and recorded by the Bureau of Standards investigators already mentioned. The order of mistake in this region is not more than ·08A.° U.

Besides the lines already recorded, I have discovered a large number of new lines which have been denoted by T. I have looked for the impurities of Si, Pb, Ag, Tl, C, Bi, As, Sb, Sn, Zn, etc., and also for air lines with the aid of the tables given in the Vols. 6 and 7 of Kayser's Handbuch der Spectroscopie.

Table (I) gives a list of the Bismuth arc lines with wave numbers and classification.

TABLE I.

List of Bismuth Arc Lines.

λ_{air} I.A.	Int.	ν_{vac}.	Classification.	REMARKS.
1902·16	1	52612	...	Probable error of ·1 A.
1909·60	2R	52352	$^4S_2-K_1$	Observed by Dr. Sur in absorption.

λ_{air} I.A.	Int.	$\nu_{vac.}$	Classification.	REMARKS.
1913·75	3	52236·3	...	
1930·42	3R	51785·0	...	T
1953·89	8R	51163·2	$^4S_2 - J_3$	
1959·48	8R	51017·3	$^4S_2 - I_2$	Bloch (1959·63).
1973·08	5	50665·7	$^2D_3 - C_2$	Bloch 1973·15.
1976·42	·5	50580·1	...	T
1984·5	2U	50374·0	...	T
1989·96	5	50235·8	...	...
2001·59	2U	49944·0	...	T
2011·39	1u	49700·7	...	T
2021·21	6R	49459·3	$^4S_2 - H_2$	Eder 2020·1 in Vac.
2023·99	5u	49391·3	...	T
2033·91	·5U	49150·5	...	T
2041·96	8	48956·8	...	T
2049·69	7R	48772·1	...	Eder 2049·59 in Vac.
2053·52	·5u	48681·2	...	T
2057·68	5	48582·8	$^2D_3 - b_2$	T
2061·70	10R	48488·1	$^4S_2 - G_3$	O. 2061·73.
2064·79	5	48415·5	...	T
2069·70	1	48300·7	...	T
2097·63	·5U	47657·6	...	T
2110·31	10R	47371·3	$^4S_2 - F_1$	O. 2110·26.
2133·69	6R	46852·3	$^2D_2 - O_2$	O. 2133·62.
2134·58	6R	46832·8	...	O. 2134·31.
2143·66	1	46634·4	...	T
2152·91	6R	46434·0	...	O. } Single broad reversal on my plates.
2153·53	6R	46420·7	...	O.
2156·96	7R	46347·0	...	...
2164·10	4R	46194·1	...	O.
2176·62	0R	45928·4	...	Ruark, etc. Very faint traces appear on one plate only.
2177·22	4R	45915·7	$^4S_2 - E_1$	Ruark, etc. 2177·33.
2189·58	8R	45656·6	$^2D_2 - N_3$	
2198·26	1R	45476·3	...	T
2202·86	2RU	45381·3	...	T
2203·12	4U	45376·0	...	O. ?

λair. I.A.	Int.	νvac.	Classification.	REMARKS.
2214·11	3R	45150·7	$^2D_2 - M_2$	...
2224·24	2	44945·1	...	O. 2224·21
2228·23	10R	44864·6	$^4S_2 - D_2$	
2230·64	10Ru	44816·4	$^4S_2 - C_3$	
2237·84	1R	44672·0	...	T [Tl. ?]
2246·77	1u	44494·5	...	T
2249·38	5	44442·9	$^2\overline{P}_1 - c_2$	T
2276·57	10R	43912·2	$^4S_2 - B_2$	...
2281·38	6u	43819·5	...	O. 2281·35
2288·00	1	43692·8	...	T
2289·98	1	43655·0	...	T
2293·87	·5u	43582·0	...	T?
2297·58	1u	43510·6	...	T
2304·94	1u	43371·7	...	T
2309·73	3U	43381·7	...	O. 2309·3
2313·80	1R	43205·6	$^4S_2 - a_3$	T
2316·1	1U	43162·7	...	T
2317·43	1r	43138·0	...	T
2328·19	7r	42938·6	...	O. 2328·24
2329·95	1	42906·2	...	T
2333·79	7	42835·6	$^2D_3 - O_2$	...
2337·49	·5	42767·8	...	T
2345·91	5u	42614·3	...	T
2347·99	0U	42576·4	...	T ?
2349·10	3	42556·5	$^2D_2 - L_2$	T
2353·61	1	42474·9	...	...
2354·60	4u	42457·0	...	O. 2354·48
2360·09	1U	42358·1	$^2\overline{P}_1 - b_2$	T.
2368·18	1r	42213·6	...	T
2369·21	6u	42195·2	...	O. 2369·17
2379·73	5u	42008·7	...	T
2400·90	10R	41638·4	$^2D_3 - N_3$	...
2409·57	2U	41488·5	...	O. 2409·62
2430·45	3u	41132·1	$^2D_3 - M_2$	...
2433·4	3U	41082·3	...	O. ?
2435·81	2U	41041·8	...	T ...
2448·30	8R	40832·3	$^2D_2 - K_1$	O. 2448·06
2489·6	3U	40155·0	...	O. 2489·4

λ air I.A.	Int.	ν vac.	Classification.	Remarks.
2499·52	10	39995·6	...	O. 2499·30
2515·68	9R	39738·7	$^2D_2 - J_3$	...
2524·53	9R	39599·5	$^2D_2 - I_2$.	...
2532·2	5U	39479·5	...	O. 2532·5
2536·56	1R	39411·63	...	T ? Hg.
2582·20	4	38715·1	...	O. 2582·15
2594·12	1	38537·2	$^2D_3 - L_2$	O. 2594·03, ν 38538·6 My measurement approx.
2600·61	0	38441·0	...	O. ?
2627·92	8R	38041·6	$^2D_2 - H_2$	...
2696·76	6R	37070·5	$^2D_2 - G_3$	...
2730·45	6u	36613·2	$^2\overline{P}_1 - O_2$	O. 2730·51
2767·88	3	36118·1	...	T
2780·52	8R	35953·9	$^2D_2 - F_1$	...
2798·74	6u	35719·8	$^2D_3 - J_3$	O. 2798·70.
2803·53	4	35658·8	...	T (Bi+) ?
2809·64	6R	35581·4	$^2D_3 - I_2$	...
2864·0	7U	34905·8	$^2\overline{P}_1 - M_2$	O. 2863·75. My measurement approxmiate.
2883·81	1u	34666·2	...	O. ?
2892·91	1u	34557·1	...	...
2897·99	9R	34496·6	$^2D_2 - E_1$	...
2938·32	9R	34023·1	$^2D_3 - H_2$	...
2944·28	0	33954·3	...	O. ?
2989·05	7R	33445·8	$^2D_3 - D_2$	...
2993·36	6R	33397·5	$^2D_2 - C_3$	...
3024·67	7R	33052·0	$^2D_3 - G_3$	...
3035·18	7u	32937·5	$^2\overline{P}_2 - C_2$	O. 3034·91
3067·73	10R	32587·9	$^4S_2 - A_1$	...
3076·69	2R	32493·0	$^2D_2 - B_2$	...
3093·58	5u	32315·7	$^2\overline{P}_1 - L_2$	T
3144·6	5U	31791·4	$^2D_2 - a_3$	T
3216·8	1U	31077·8	...	T
3239·73	5	30887·9	$^2\overline{P}_2 - b_2$	T
3267·97	1u	30591·2	$^2\overline{P}_1 - K_1$	T
3302·55	1·5	30270·9	...	T
3361·23	·5	29742·5	...	T

λ air I.A.	Int.	ν vac.	Classification.	REMARKS.
3382·28	1	29557·4	...	T
3397·29	5R	29426·8	$^2D_3 - D_2$	O. 3397·21.
3402·80	3	29379·2	$^2D_3 - C_3$	T
3405·63	7u	29354·7	$^2\overline{P}_1 - I_2$	O. 3405·23
3510·96	6u	28474·2	$^2D_3 - B_2$	O. 3510·85.
3519·18	3	28407·6	...	T
3596·11	3R	27799·9	$^2\overline{P}_1 - H_2$	...
3599·94	1	27770·4	$^2D_3 - a_3$	T
3619·37	2	27621·3	...	T
3775·75	1	26477·3	...	...
3887·94	2	25713·3	$^2\overline{P}_1 - F_1$	...
3888·22	2	25711·4	$^2\overline{P}_1 - F_1$	...
3912·90	1	25553·2		O. ?
4116·35	·5	24286·5	...	T
4121·52	5	24256·1	$^2\overline{P}_1 - E_1$	...
4121·84	5	24254·2	$^2\overline{P}_1 - E_1$	...
4127·36	·5u	24221·8	...	T
4220·83	2	23685·3	...	T
4254·15	1	23499·9	$A_1 - \xi$	$\xi = 2475$.
4260·06	·5U	23467·3	...	T
4308·17	4	23205·2	$^2\overline{P}_1 - D_2$	...
4308·53	4	23203·3	$^2\overline{P}_1 - D_2$	...
4492·61	1	22252·6	} $^2\overline{P}_1 - B_2$	...
4492·97	1	22250·8		
4615·15	1	21661·7	} $^4S_2 - {}^2\overline{P}_1$	
4615·60	1	21659·6		
4692·32	1u	21305·5	$A_1\ \psi$	
4716·38	1	21197·8	...	$\psi = 4670$.
4722·19	10	21170·7	T	} T ...
4722·54	10	21169·1	$^2D_2 - A_1$	...
4722·83	10	21167·8		
4728·96	1	21140·4	...	T
4733·78	2r	21118·9		
5298·36	1u	18868·5		
5552·23	7r	18005·8		...
5599·41	3	17854·1	$^2\overline{P}_2 - I_2$	
5718·81	2	17481·3		
5742·59	3r	17408·9		

λ air I.A.	Int.	ν vac.	Classification.	REMARKS.
6134·86	2	16295·8	$^2\overline{P}_2 - H_2$	
6184·99	2U	16163·7		
6364·75	1u	15707·2		
6475·73	3	15438·0	$\left.\right\} {}^4S_2 - {}^2D_3$	
6476·24	3	15436·8		
6991·12	4 u	14299·9		
7036·15	2	14208·4	$^2\overline{P}_2 - F_1$	
7335·01	1	13629·5		
7441·25	1u	13434·9		
7502·33	2	13325·5		
7838·70	3	12753·7		
7840·33	2	12751·1	$^2\overline{P}_2 - E_I$	
8210·83	16	12175·7	$B_2 - \xi$	$\xi = 2475$
8501·8	1U	11759·0		
8544·54	2	11700·2	$^2\overline{P}_2 - D_2$	
8579·74	1	11652·2	$^2\overline{P}_2 - C_3$	
8627·9	1u	11587·1		
8754·88	2	11419·1	$^4S_2 - {}^2D_2$	
8761·54	3	11410·4		
8907·81	2	11223·0	$D_2 - \xi$	$\xi = 2475$.
9058·62	1	11036·2		
9342·60	1u	10700·7		
9657·2	300	10352·1		

λ Rowland.	Int.	ν vac.	Classification.	REMARKS.
9828·8	20	10171·4	$E_I - \xi$	$\xi = 2475$.
10106·1	20	9892·3		
10301·7	15	9704·5		
10540·2	8	9484·9		
11073·2	25	9028·4	$D_2 - \psi$	$\psi = 4670$.
11555·5	5	8651·5		
11711·1	100	8536·6		
11994·5	13	8334·9		
12166·5	40	8217·1		
12690·5	30	7877·8		
14331·5	25	6975·7		
22254·2	7	4432·6	$H_2 - \psi$	$\psi = 4670$.

Theoretical Considerations.

Bismuth belongs to the group of five-valence electrons (N, P, As, Sb), and it may be recalled that the spectra of none of these elements have been completely elucidated. Fowler[1] has classified the lines of O^+ but he could not trace the fundamental levels. Millikan and Bowen[2] have discovered some of the fundamental levels of O^+ in the extreme ultra-violet, but the mutual relation of the inter-combination systems has not yet been completely established. A discussion of the structure of the spectrum of O^+ from the standpoint of Hund's theory has been given by R. H. Fowler and D. Hartree.[3]

Electron Composition of Bismuth.

2 K	8 L	18 M	32 N	
	O_1	O_2	O_3	O_4
	2	6	10	
		P_1	P_2	P_3
		2	3	

$$\begin{tikzcd} P_2 \arrow[r] \arrow[d] & P_3 \arrow[d] \\ Q_1 \arrow[r] & Q_2 \arrow[d] \\ & R_1 \end{tikzcd}$$

For detailed explanation, see a paper by Kichlu and Saha "On the Explanation of Anomalous Terms in The Spectra of Two-valence Elements (Phil Mag., July, 1927).

The letters K, L, M, denote the X-Ray levels, and the numbers under them represent the number of electrons in the level. Possible transitions giving rise to the line spectra are indicated by arrows.

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[1] A. Fowler, P. R. S. (Lond.), A. Vol. 110, p. 476 (1926).
[2] Millikan and Bowen, Nature, September, 1926, p. 410.
[3] R. H. Fowler and D. Hartree, P. R. S. (Lond.), A. 111, 83 (1926).
For Nitrogen see Keiss, Jour. Opt. Soc. Amm, July, 1925.
For Phosphorus, Miss Saltmarsh, Phil. Mag., Vol. XLVII, 874 (1924).

The combinations and the expected terms are given below :—

$$\begin{tikzcd}[row sep=small]
 & 2P_2Q_1 \arrow[ddr] & \\
 & S & \\
3P_2 \arrow[uur] \arrow[ddr] & [{}^4P, {}^2\overline{P}, {}^2D, {}^2S] & P_2Q_2 \\
[{}^4S_2, {}^2D_{2,3}, {}^2\overline{P}_{1,2}] & & \begin{bmatrix} {}^4D, & {}^4\overline{P}, & {}^4S \\ {}^2D, & {}^2\overline{P}, & {}^2S \end{bmatrix} \\
 & 2P_2P_3 \arrow[uur] & \\
 & \begin{bmatrix} {}^4F, & {}^4\overline{D}, & {}^4P \\ {}^2F, & {}^2\overline{D}, & {}^2P \end{bmatrix} & \\
 & \text{etc.} &
\end{tikzcd}$$

Explanation.—$3P_2$ indicates that all the 3-valence electrons are at P_2-level. $2P_2Q_1$ indicates that one has gone over to Q_1, etc. The terms arising from any combination according to the theory of structure of complex spectra, are shown below that combination. Attention is drawn to the fact that in the symbols $3P_2$, $2P_2Q_1$, $2P_2P_3$, etc., P indicates the particular shell in the atom numbered according to the convention, K, L, M, ... But ${}^2P_{1,2}$, etc. in the brackets indicate spectral terms having P-characteristics. The confusion is regretted, but is unavoidable.

Bismuth being a heavy element will show abnormally wide separations in the values of the terms arising from the the same electronic combination. I have, therefore, started with the theoretical spectrum of Bi^+ of which the fundamental levels are ${}^3P_{0,1,2}$, ${}^1\overline{D}_2$, ${}^1\overline{S}_0$. To calculate the terms of Bi, I have taken each one of these optical levels, and brought a fresh electron to each of the outer levels, and calculated the possible orbits. This is shown in Chart I and then the range in value of the terms are discussed below, and their identification is carried out in Table II.

CHART I

Combination.		Sommerfeld's J-value.	Lande's J-value.	Term.	Identification.
$2P_2Q_1$	$(^3P_0)\ ^2S_{1/2}$	1/2	1	$^4P_1$	A_1
	$(^3P_0)\ ^2S_{1/2}$	1/2	1	$^2P_1$	E_1
		3/2	2	$^4P_2$	D_2
	$(^3P_2)\ ^2S_{1/2}$	3/2	2	$^2P_2$	H_2
		5/2	3	$^4P_3$	G_3
$2P_2P_3$	$(^3P_0)\ ^2D_{3/2,5/2}$	3/2	2	X_2	B_2
		5/2	3	X_3	C_3
	$(^3P_1)\ ^2D_{3/2,5/2}$	1/2	1		
		3/2	2		I_2
		5/2	3		J_3
		3/2	2		
		5/2	3		
		7/2	4		
	$(^3P_2)\ _2D_{3/2,5/2}$	1/2	1		
		3/2	2		
		5/2	3		
		7/2	4		
		1/2	1		
		3/2	2		
		5/2	3		
		7/2	4		
		9/2	5	$^4F_5$	

TABLE II.

	$^4S_2$	$^2D_2$	$^2D_3$	$^2\bar{P}_1$		$^2\bar{P}_2$	Term Value.
$2P_2Q_1$ $(^3P_0\ ^2S_{1/2})$ A_1 $^4P_1$	32587·9 3067·73 (10 R)	21170·7 21169·1 21167·8 4722·19 4722·54 4722·83 (10) (10) (10)	...	(10927)		–ve	25975
$2P_2P_3$ $(^3P_0\ ^2D_{3/2})$ B_2	43912.2 2276·57 (10R)	32493·0 3076·69 (2R)	28474·2 3510 96 (6u)	22252·6 4492·61 (1)	22250·8 4492·97 (1)	...	14650
$2P_2P_3$ $(^3P_0\ ^2D_{5/2})$ C_3	44816·4 2230·64 (10Ru)	33397·5 2993·36 (6R)	29379·2 T 3402 80 (3)	... ...		11652·2 8579·74 (1)	13746
$2P_2Q_1$ $(^3P_1\ ^2S_{1/2})$ D_2	44864·6 2228·23 (10R)	33445·8 2989·05 (7R)	29426·8 3397·29 (5R)	23205·2 4308·17 (4)	23203·3 4308·53 (4)	11700·2 8544·54 (2)	13698
$2P_2Q_1$ $(^3P_1\ ^2S_{1/2})$ E_1	45915·7 2177·22 (4R)	34496·6 2897·99 (9R)	... ...	24256·1 4121·52 (5)	24254·2 4121·84 (2)	12751·1 7840·33 (2)	12647

$2P_2R_1$ F_1	47371·3 2110·31 (10R)	35953·9 2780·52 (8R)	... ...	25713·3 25711·4 3887·94 (2) 3888·22 (2)	14208·4 7036·15 (2)	11190
$2P_2Q_1$ $(^3P_2S_{1}/_{2})$ G_3	48488·1 2061·70 (10R)	37070·5 2696 76 (6R)	33052·0 3024·67 (7R)	...	(15326)	10073
$2P_2Q_1$ $(^3P_2\ ^2S_{1}/_{2})$ H_2	49459 3 2021·21 (6R)	38041·6 2627·92 (8R)	34023·1 2938·32 (9R)	27799·9 3596·12 (3R)	16295·8 6134·86 (2)	9102
$2P_2P_3$ $^3P_1\ ^2D_{3}/_{2})$ I_2	51017·3 1959 48 (8R)	39599·5 2524·53 (9R)	35581·4 2809·64 (6R)	29354·7 3405·63 (7u)	17854·1 5599·41 (3)	7544
$2P_2P_3$ $(^3P_1\ ^2D_{5}/_{2})$ J_3	51163·2 1953·89 (8R)	39738·7 2515·68 (9R)	35719·8 2798·74 (6u)	...	(17993)	7405
$2P_2S_1$ K_1	52252 1909·6 (2R)	40832·3 2448·30 (8r)	...	30591·2 T 3267·97 (1u)	(19086)	6311
$2P_2R_3$ L_2	(53975)	42556·5 T 2349·10 (3)	38538·6 2594·03 (1)	32315·72 T 3093·58 (5u)	(20810)	4587
M_2	(56569)	45150·7 2214 11 (3R)	41132·1 2430·45 (u)	34905·8 2864·01 (7u)?	(23406)	1993

	$^4S_2$	$^2D_2$	$^2D_3$	$^2\bar{P}_1$	$^2\bar{P}_2$	Term Value.
N_3	(57075·4)	45656·6 2189·59 (8R)	41638·4 2400·90 (10R)	...	(23912)	1487
O_2	(58271·1)	46852·3 2133·69 (6R)	42835·6 2333·79 (7)	36613·2 2730·45 (6u)	(25109)	291
a_3	43205·6 T 2313·8 (1R)	31791·4 T ? 3144·6 (5U)	27770·4 T 3599·94 (1)	...	...	
b_2	(64019)	(52601)	48582·8 T 2057·68 (5)	42358·1 2360·1 (1U)	30854·8 T 3239·73 (5)	
c_2	(66102)	(54684)	50665·7 1973·08 (5)	44442·9 (T) 2249·38 (5)	32937·5 (T) 3035·18 (3u)	

(*a*) *The Fundamental levels.*

Five fundamental levels are expected $^4S_2$, $^2D_{2,3}$, $^2\overline{P}_{1,2}$. It is natural to identify them with the levels discovered by Kayser and Runge, but several discrepancies have to be removed.

A glance at the Table II shows that the first two levels have the same combinatory powers up to the sub-level denoted by J. The only discrepancy was in the level E. There are two close lines λ2177·22 and λ2176·62, and, according to Ruark, etc., it is the shorter line which is the more intense and easily absorbed. But my measurements show that the longer line λ2176·22 is the more intense and is always obtained in absorption, while the line λ2176·61 appear very faintly on one plate only. With this correction, E fits in well under both levels.

Beyond this level the lines which arise from combination with $^4S_2$ fall in the Schumann region. Bloch has given data for this region, but they do not seem to be reliable.

The third level has the j-value 3, for it gives fewer combinations. I have specially looked for the lines $^2D_3$—E and $^2\overline{P}_1$—C, but they are definitely absent.

The close levels $^2\overline{P}_1$, having the separation 1·91, have probably the same inner quantum number 1, and differ only in the "fine quantum number" introduced by Ruark.[1]

I have provisionally identified the fifth level $^2\overline{P}_2$ with Ruark's "β." This is a bit doubtful.

(*b*) *The next levels arise from the combinations.*

$$\left.\begin{matrix} 2P_2Q_1 \\ 2P_2P_3 \end{matrix}\right\}$$

We have to identify these levels with the levels denoted by A, B, C, D, ... etc., and a mere glance at the chart shows that there is a wide divergence in the scale of values of these terms. We are here encountering terms of

[1] Ruark, Phil. Mag., Vol. 50, p. 937 (1925).
Sommerfeld, Three Lectures on Atomic Theories, page 12.

the "displaced Type" first discovered by Paschen[1] in the spectrum of Neon, and since confirmed by Grotrian[2] and Sur[3] in the spectrum of Pb. We shall take the discussion of this point in detail.

The fundamental terms of Bi^+ are given by the combination $^2P_2$ giving us the terms

$$^3P_0, \quad ^3P_1, \quad ^3P_2, \quad ^1\bar{D}_2, \quad ^1\bar{S}_0$$

similiar to those of lead. In the case of Pb,

$$^3P_0 - {}^3P_1 = 7{,}817.$$
$$^3P_1 - {}^3P_2 = 2{,}831.$$

In the case of Bi^+ we assume that

$$^3P_0 - {}^3P_1 = 16{,}000.$$
$$^3P_1 - {}^3P_2 = 6{,}000.$$

When we form Bi by bringing another electron, either in position Q_1 or in P_3, it is comparatively lightly coupled to the inner electrons. We can classify the new terms from $2\,P_2\,Q_1$, and $(2P_2)\,P_3$ in three groups, *viz.*, (1) from $^3P_0$-state; (2) from $^3P_1$-state; (3) from $^3P_2$-state of Bi^+; and we expect that these groups are approximately separated by the values $^3P_0 - {}^3P_1$, $^3P_2 - {}^3P_2$. These three groups are shown in the tabulated form in Chart $\bar{\text{I}}$.

In calculating the resultant j-values, we have assigned the Sommerfeld j-values to each term. This is shown in column 2. In column 3, the convential or Lande j-values are given. This is Sommerfeld's $j+\frac{1}{2}$.

It will be seen that we get three terms from $^3P_0$-level, *viz.*, $^4P_1$, X_2 and X_3. In analogy with Pb, since $^4P_1$ arises from the electron configuration $2P_2Q_1$ we may assign to $^4P_1$ the approximate value $\frac{N}{2^2}$, and to X_2X_3 the value $\frac{N}{3^2}$ $(2P_2P_3)$. We have therefore no difficulty in identifying $^4P_1$, X , X_3 with A, B and C respectively.

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[1] Paschen, Ann. der Phy., Vols. 60 and 63.
[2] Grotrian, Zeit. f. Phy., Vol. 39.
[3] Sur, Phil. Mag. (on the Spectrum of Pb. to be published); Meissner, Zeit. f. Phy., Vol. 38, page 647.

The $(^3P_1)\,^2S$ terms will be less than $(^3P_0)\,^2S$ or $^4P_1$ by about 16,000. Hence we may identify these as :—

$$D = {}^4P_2 \quad \text{and} \quad E = {}^2P_1.$$

The $(^3P_1)^2D$-terms will be very small or may be even negative.

The terms arising from $(^3P_2)\,^2S$ can be easily identified with G and H. The inner quantum numbers are in perfect agreement.

These identifications leave out the term F with $j=1$, and Thorsen is therefore justified in identifying it as the higher Rydberg number of A, *i.e.*, $2P_2\ R_1$.

In Table III we give lines which probably form a Rydberg sequence.

TABLE III.

	$^4S_2$.	$^2D_2$.	$^2\overline{P}_1$.	$^2\overline{P}_2$.
	32587·9	21169·1	...	...
	3067·73	4722·54	...	...
X_1	47372·4	35953·8	25713·3	14208·4
	2110·26	2780·53	3887·94	7036·15
	52252·	40832·3	30591·2	...
	1909·6	2448·30	3267·97	...

The lines under the heading $^2D_2$ are given by the Hicks's formula :—

$$V = 47{,}143 - \frac{N}{\left(m + \cdot 28143 - \frac{\cdot 45324}{m}\right)^2}$$

$m = 2, 3, 4,$

Thorsen gives $^2D_2=47323$. It is due to the fact that he gave the third row incorrectly. The line λ3267·97 predicted by Thorsen appeared on my plates. The first line of the third row is given by Thorsen as λ1913·6. Dr. Sur has always got the line λ1909·6 in absorption and as this fits in the scheme there is no doubt that this is the line looked for. I have been unable to identify the higher numbers predicted by Thorsen, or numbers arising from my formula. The terms arising from ($^3P_0$) $^2D_{3/2}$ *viz.*, in the electron configurations $2P_2$ (P_3), $2P_2$ (Q_3), $2P_2$ (R_3), will form a regular Rydberg sequence. The lines provisionally identified are given below.

TABLE IV.

	$^4S_2$	$^2D_2$	$^2D_3$	$^2\bar{P}_1$	$^2\bar{P}_2$
	43912·0	32493·2	28475·0	22252·6	...
	2276·57	3076·67	3510·85	4492·61	
X_2	51017·3	39599·6	35581·5	29358·2	17854·1
	1959·48	2524·52	2809·63	3405·63	5599·41
	(53975)	42556·5	38538·6	32315·7	(20810)
		2349·10	2594·03	3093·58	

The three lines under $^2D_2$ can be represented by the formula

$$v=43{,}314-\frac{N}{\left(m-{\cdot}08059-\frac{{\cdot}59766}{m}\right)^2}$$

$m=3, 4, 5.$

It is seen that the limits calculated from both the sets come almost to the same value.

Table V shows the lines which form a regular Rydberg sequence with terms X_3 arising out of the combination $^3P_0$ $^2D_{5/2}$

TABLE V.

	$^4S_2$	$^2D_2$	$^2D_3$	$^2\overline{P}_1$	Term value.
	44816·4 2230·64	33397·5 2993·36	29379·2 3402·80(3)	...	13746
X_3	51163·2 1953·89	39738·7 2515·68	35719·8 2798·74 (6u)	..	7405
	(54032)	42614·3 2345·91 (5u)	(38596)	...	4529

The lines under $^2D_2$ may be easily grouped under a Rydberg sequence. The last term is a bit doubtful.

No regular Rydberg sequence except these three are expected. The terms arising out of $^3P_1$ or $^3P_2$ will form regular sequences if 16,000 and 6,000 approximately are added to them. Hence all the terms after the first will become very small or negative. Unless the spectrum is investigated in the Flourite region, it will be difficult to identify them.

Lines occurring as the result of inter-combination between the states $2P_2P_3$, $2P_2$ Q and $2P_2Q_2$, $2P_2Q_1$, have been looked for from the existing data, but only the following have been found :

λ	ν	
4254·15	23499·9	A_1-2475
8210·83	12175·7	B_2-2475
8907·81	11223·0	D_2-2475
9828·8	10171·4	E_1-2475

The above was found by Ruark and others; in addition to this I find the one given below:

λ	ν	
4692·32	21305·5	$A_1 - 4670$
1107·32	9028·4	$D_2 - 4670$
22254·2	4432·6	$H_2 - 4670$

It seems that the existing data is not sufficient to establish the inter-combination terms and hence the region $\lambda 4800$— $\lambda 8000$ is now being investigated.

In conclusion I wish to thank Prof. M. N. Saha under whose direction and guidance this investigation has been carried on. I am also much obliged to Dr. N. K. Sur for his supplying me with some of his unpublished data on Bismuth under-water spark and absorption spectra of Bismuth.

MEASUREMENT OF CAPACITY AND HIGH RESISTANCE BY MEANS OF A THERMIONIC VALVE

BY

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INTRODUCTION.

The use of thermionic valve, an instrument found in every physical laboratory nowadays, is confined not only to "Radio," but of late has largely been extended to the measurements of voltage and capacity. John Scott Taggart[1] and several others using heterodyne methods, while Karolus and Prince,[2] Gorbatscheff[3] and Dowling[4] using other methods, were not successful in measuring capacities of the order of a few cms., although they succeeded in measuring small changes in capacity. Further these methods were not so simple and handy as the one now described. The quadrant electrometer methods used by Mukerjee[5] and others are very elaborate and inconvenient. Bridge method recently developed by Hartshorn[6] may be quite handy, but different methods using entirely different principles and instruments provide greater convenience in the measurement of a quantity.

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[1] Taggart : Electrician, April (1919).

[2] Karolus and Prince : Phys. Zeits., 22, 362 (1921).

[3] K. Gorbatscheff : Phys. Zeits., 25, 485 (1924).

[4] J. J. Dowling : Roy. Dub. Soc. Pro., 16, 175 (1920).

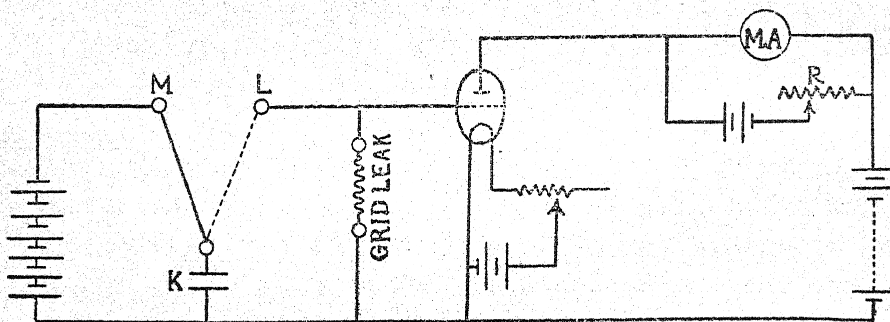
[5] A. T. Mukerjee : Phil. Mag., 38 (1919).

[6] L. Hartshorn : Phy. Soc. Pro., 36, 399 (1924).

Dowling[1] made use of the cumulative grid rectification property of the valve and found that the relation between capacity and galvanometer deflection was linear, but he too was obliged to use metallic screening to avoid unsteadiness of the galvanometer. The method now to be described dispenses altogether with screening and is capable of measuring capacities as low as 5 cms. within 1 p.c. with necessary precautions and suitable galvanometer.

EXPERIMENTAL ARRANGEMENT.

The arrangement used is shown schematically below.



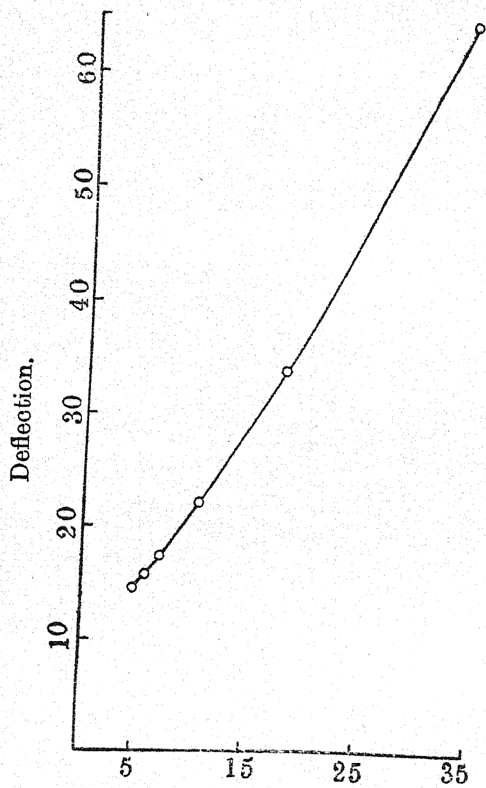
The figure given above is self-explanatory. K is a condenser which is charged as shown by the battery on the extreme left. The initial anode-filament current is balanced by a separate battery and a continuously variable resistance. The balancing resistance R should be much greater than the resistance of the microammeter M. A. The anode potential is such that with no grid bias, the zero grid line comes to the middle portion of the characteristic curve. K is then discharged through the grid-filament circuit, by connecting K to L as shown by the dotted line. Suitable value of the grid leak is chosen so

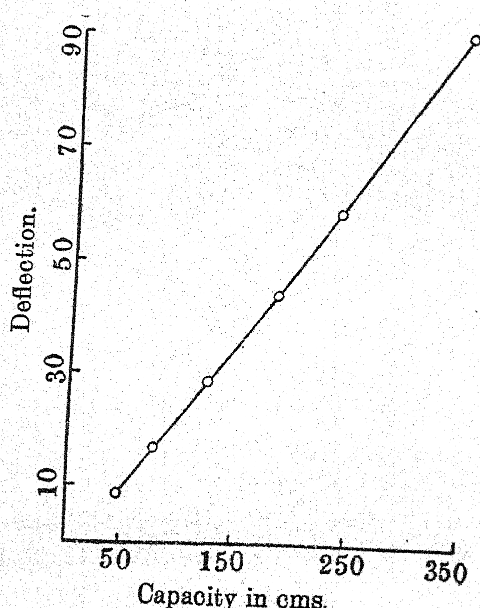
[1] Dowling: Loc. cit.

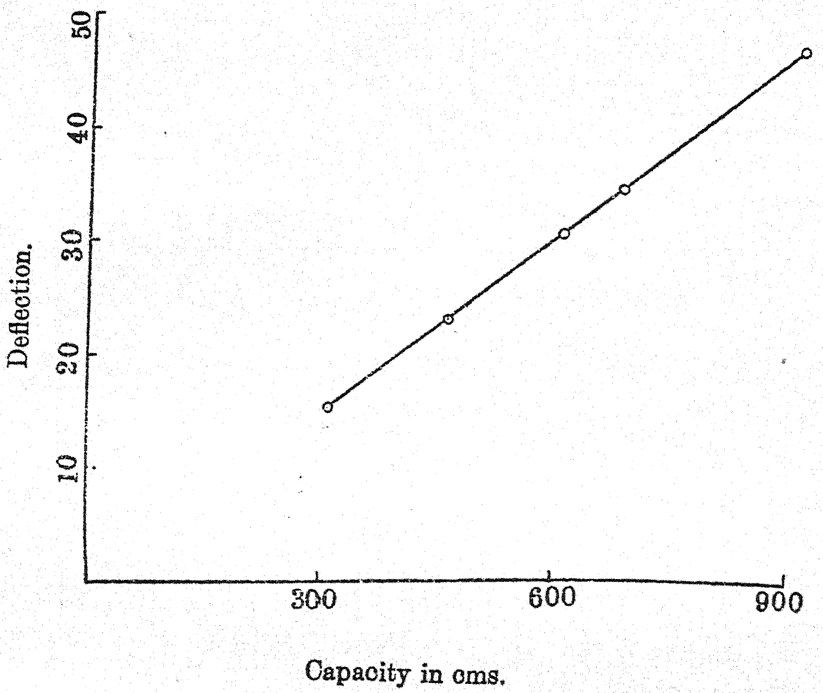
that with the capacities to be measured the deflection in M. A. is not greater than the range of the instrument. With these precautions the deflections for various values of K and grid leak were noted and graphs plotted.

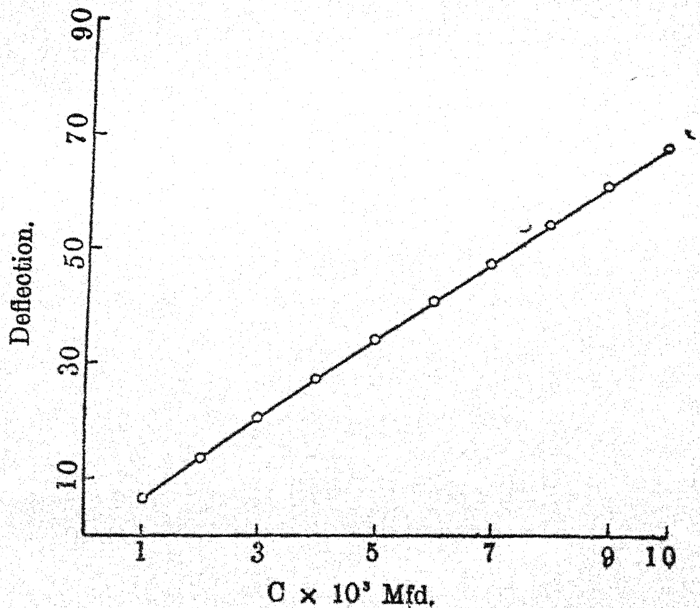
Charging voltage.	Grid leak.	Capacity.	Deflection.
20 Volts.	None.	·5 cms.	14
		5·8 cms.	15
		7 cms.	16
		10 cms.	20
		17·5 cms.	31
		35 cms.	61

Charging Volts.	Grid leak.	Capacity.	Deflection.
10·2	Lead pencil line	35 cms.	8·0
		70 ,,	16·0
		116·6 ,,	28·0
		175 ,,	43·5
		233·3 ,,	57·5
		350 ,,	88·5
10·2	6 Megohms	300 cms.	16·0
		450 ,,	24·5
		600 ,,	32·0
		675 ,,	36·0
		900 ,,	48·5
10·2	·66 Megohm	$1 \times 10^{-3} \mu$ F.	7·5
		2	14·0
		3	21·0
		4	27·5
		5	34·5
		6	41·0
		7	48·0
		8	55·5
		9	62·0
		10	69·0


Deflection.
10
20
30
40
50
60
5
15
25
35

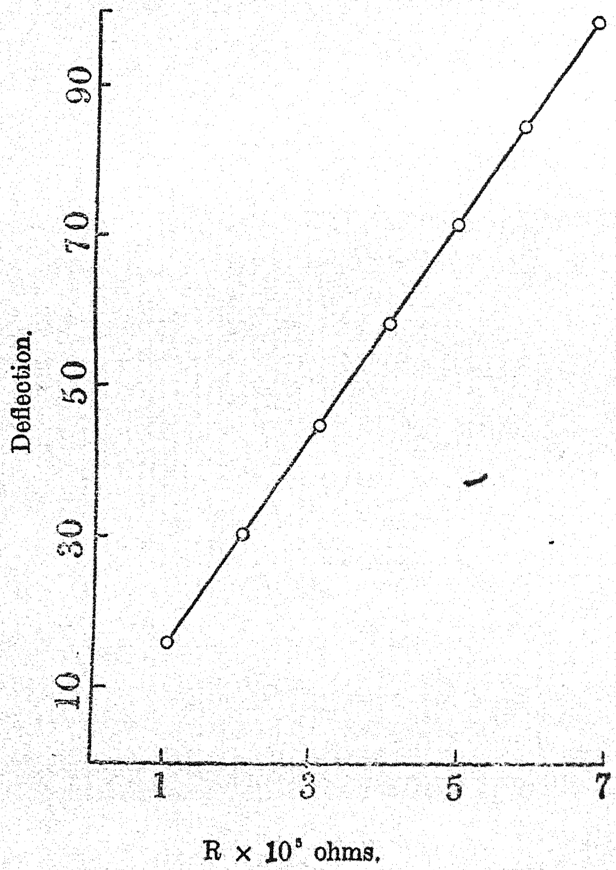

Deflection.
10
30
50
70
90
50
150
250
350
Capacity in cms.


Deflection.
10
20
30
40
50
300
600
900
Capacity in cms.


Deflection.
10
30
50
70
90
1
3
5
7
9
10
C × 10³ Mfd.

Taking a suitable condenser and varying the grid leak it was found that a linear relation existed between the grid leak resistance and the deflection. A typical set of readings with a corresponding graph is appended.

Charging Volts.	Capacity.	Grid leak.	Deflection.
10·2	·048 μ. F.	1×10^5 ohms.	16·0
		2	30·0
		3	44·5
		4	57·0
		5	70·5
		6	83·0
		7	96·5



DISCUSSION OF THE RESULTS.

Leaving aside the 1st graph for very small capacities, it is evident that a linear relation exists between the capacity and the momentary deflection in the microammeter. From the observations and otherwise too it is quite apparent that we are not dealing with amplification of the quantity of electricity actually discharged through the grid-filament circuit. When a certain quantity of electricity is discharged through this circuit, due to the capacity effect of the electrodes, the grid is momentarily charged to a certain voltage and we get a corresponding kick in the microammeter. The voltage thus applied to the grid then evidently depends upon the quantity of electricity discharged through grid-filament which in turn depends upon the grid leak. In the anode circuit we are also dealing with a momentary current, *i.e.*, a quantity of electricity and hence it is to be expected that the deflections will be directly proportional to the capacity K in case a ballistic galvanometer is used. Using the latter instrument it was actually found to be the case. But the results given here are all those obtained by using the microammeter as it is certainly more handy and convenient to use.

In the case of Graph 1, a parallel plate condenser was used, and as it was not provided with a guard ring, the simple formula $C = \frac{A}{4\pi d}$, does not rigidly hold, and is likely to introduce some curvature in the relation. This curvature can also be attributed to the fact that the capacity of connecting wires, etc., becomes a considerable factor. But as we go on using higher and higher capacities, this curvature disappears and the relation becomes linear.

The familiar equation connecting plate current, plate potential and grid potential is

$$I_p = A\,(E_p + \mu\, E^g).$$

$$\therefore \delta I_p = A\mu\ \delta\, E_g \qquad \ldots \quad (1)$$

The quantity of electricity discharged through the anode circuit is

$$Q = \int \delta\, I_p\, dt$$

$$= A\mu \int \delta\, E_g\, dt \quad \ldots \ (2)$$

Assuming that the grid-filament resistance is infinite, the grid voltage at any instant is given by

$$\delta\ E_g = E.\ e^{\frac{-t}{(C+K)\ G}} \quad \ldots \ (3)$$

where E=the E. M. F. of the charging battery.

C=Grid=Filament capacity.

G=Grid=leak resistance.

K=Capacity of the condenser.

Hence, from (2) and (3)

$$Q = A\,\mu\, E \int_0^{\infty} e^{\frac{-t}{(C+K)\ G}}\ dt.$$

$$= A\ E\ (C+K)\ G\ \mu.$$

$$= A\ E\ K\ G\ \mu$$

when $C << K$.

In conclusion I wish to thank Prof. M. N. Saha and Mr. S. R. Bhargava for their kindly help and interest shown throughout the progress of the work.

ABSTRACT.

Charging a capacity by means of a suitable battery and discharging it through the grid-filament circuit, provided with a suitable grid-leak, it has been found possible to determine the value of a very small capacity, by noting the change in the anode current. By a similar process, values of high resistances have also been found out.

SECTION IV

CHEMISTRY

VISCOSITY OF SOLS IN PRESENCE OF ELECTROLYTES

BY

D. N. CHAKRAVARTI, M. N. CHAKRAVARTI AND
N. R. DHAR.

In previous publications[1] from these laboratories, it has been shown that the viscosity of colloids decreases appreciably on the addition of small quantities of electrolytes. Hence we have concluded that the increase of charge on a colloid is always associated with a decrease of the viscosity and the amount of hydration of a colloid. In our investigations with numerous sols we have always found that on the addition of small quantities of electrolytes, the viscosity becomes appreciably less. On the addition of further quantities of electrolytes the viscosity again increases and long before coagulation sets in, the viscosity of a sol in presence of an electrolyte is greater than that of the original sol. Moreover, we have shown that on dialysing sols of vanadium pentoxide, ceric hydroxide, etc., jellies could be obtained. We have explained all these observations on the view that the viscosity and hydration of a sol are greater, the less the amount of charge. Moreover, we have also shown that those ions which are highly adsorbed by a sol produce greater lowering in the viscosity than ions, which are not so highly adsorbed.

The decrease in viscosity in the case of arsenious sulphide in presence of KCl is about 3% whilst in the

[1] J. Phys. Chem. *29*, 1556 (1925); *30*, 1646 (1926); Zeit. anorg U. allg. Chem. *152*, 393 (1926); Koll. Zeit. *42*, 124 (1927).

case of ferric hydroxide in presence of the same electrolyte the decrease of viscosity is 1·2 per cent; this is because arsenious sulphide adsorbs more Cl ions than ferric hydroxide can adsorb K ions. Consequently the charge on the sol of arsenious sulphide is increased to a greater extent than in the case of ferric hydroxide and hence the decrease in viscosity is more marked in the case of arsenious sulphide sol than in the case of ferric hydroxide sol.

It is well-known that ferrocyanide ions are appreciably adsorbed by sols of prussian blue and copper ferrocyanide and hence in presence of potassium ferrocyanide these sols show more marked decrease in viscosity than in presence of other electrolytes. We have shown in previous papers that arsenious sulphide sol is stabilised by H_2S and NaHS. From our experimental results it will be seen that arsenious sulphide in presence of NaHS shows greater decrease in viscosity than in presence of small quantities of other electrolytes. Similarly in presence of ferric chloride, hydrochloric acid, etc., there is more marked lowering of viscosity of a sol of ferric hydroxide than in presence of KCl.

In this paper we are recording further experimental results in support of the above views. Moreover, we have been able to show mathematically that the surface of a colloid particle becomes less when the amount of charge on it is increased.

EXPERIMENTAL RESULTS.

Thorium hydroxide sol prepared in the cold by the hydrolysis of thorium nitrate.

Table I.

Thorium hydroxide sol (cold) and KI.
Concentration of the sol = 4·25 gms. of ThO_2 per litre.

Temp. 25°

	Time of rise		Time for fall		Viscosity
Water					0·00894
20 c.c. sol and 5 c.c. water	4 min.	53 sec.	10 min.	5 sec.	0·00915
20 c.c. sol and 5 c.c. M/500 KI	4 ,,	52 ,,	10 ,,	4 ,,	0·00912
20 c.c. sol and 5 c.c. N/200 KI	4 ,,	51 ,,	10 ,,	0 ,,	0·00911
20 c.c. sol and 5 c.c. N/100 KI	4 ,,	51 ,,	10 ,,	0 ,,	0·00911
20 c.c. sol and 5 c.c. N/50 KI	4 ,,	52 ,,	10 ,,	11 ,,	0·00915
20 c.c. sol and 5 c.c. N/10 KI	5 ,,	5 ,,	10 ,,	24 ,,	0·00949
20 c.c. sol and 5 c.c. N/1 KI	5 ,,	20 ,,	10 ,,	42 ,,	0·00989

Table II.

Thorium hydroxide (cold) and Th $(NO_3)_4$
Concentration of the sol = 4·25 gms. of ThO_2 per litre.

Temp. 25°

Water					0·00894
Sol and water					0·00915
20 c.c. sol and 5 c.c. M/100 Th $(NO_3)_4$	4 min.	53 sec.	10 min.	4 sec.	0·00914
20 c.c. sol and 5 c.c. M/50 Th $(NO_3)_4$	4 ,,	51 ,,	9 ,,	57 ,,	0·00906
20 c.c. sol and 5 c.c. M/2·5 Th $(NO_3)_4$	5 ,,	22 ,,	10 ,,	22 ,,	0·00985

Thorium hydroxide sol was also obtained by boiling Thorium nitrate solution and dialysing it.

Table III.

Thorium hydroxide (hot) sol and KI.

Concentration of the sol = 4·82 gms. per litre.

Temp. 25°

Different viscosity tube "B"

Water	4 min.	36 sec.	11 min.	10 sec.	0·00894
20 c.c. sol and 5 c.c. water	4 ,,	42 ,,	11 ,,	17 ,,	0·00910
20 c.c. sol and 5 c.c. N/500 KI	4 ,,	41 ,,	11 ,,	15 ,,	0·00908
20 c.c. sol and 5 c.c. N/100 KI	4 ,,	39 ,,	11 ,,	14 ,,	0·00906
20 c.c. sol and 5 c.c. N/50 KI	4 ,,	39 ,,	11 ,,	12 ,,	0·00905
20 c.c. sol and 5 c.c. N/10 KI	4 ,,	56 ,,	12 ,,	12 ,,	0·00964
20 c.c. sol and 5 c.c. N/5 KI	5 ,,	27 ,,	12 ,,	24 ,,	0·01015

Table IV.

Thorium hydroxide (hot) sol and Th $(NO_3)_4$.

Concentration of the sol = 4·82 gms. of ThO_2 per litre.

Temp. 25°

Viscosity tube "B"

Water					0·00894
20 c. c. sol and 5 c. c. water	4 min.	42 sec.	11 min.	17 sec.	0·00910
20 c. c. sol and 5 c. c. M/500 Th $(NO_3)_4$	4 ,,	41 ,,	11 ,,	14 ,,	0·00910
20 c. c. sol and 5 c. c. M/ Th100 $(NO_3)_4$	4 ,,	38 ,,	11 ,,	12 ,,	0·00899
20 c. c. sol and 5 c. c. M/50 Th $(No_3)_4$	4 ,,	41 ,,	11 ,,	14 ,,	0·00906
20 c. c. sol and 5 c. c. M/25 Th $(No_3)_4$	5 ,,	12 ,,	11 ,,	23 ,,	0·00979

Table V.

Ceric hydroxide sol (hot) and KCl.

50 gms. of ceric ammonium nitrate dissolved in 250 c. c. of water and the solution was boiled over a direct flame for about 15 minutes. The sol was then dialysed for 7 days. The concentration of the sol=13·18 gms. of CeO_2 per litre.

Temp. 25°

Water			0·00894
20 c. c. sol and 5 c. c. water	4 min. 56 sec.	9 min. 57 sec.	0·00918
20 c. c. sol and 5 c. c. N/500KCl	4 „ 52 „	9 „ 55 „	0·00907
20 c. c. sol and 5 c. c. N/100KCl	4 „ 53 „	9 „ 56 „	0·00910
20 c. c. sol and 5 c. c. N/50 KCl	4 „ 55 „	10 „ 0 „	0·00916
20 c. c. sol and 5 c. c. N/20 KCl	5 „ 3 „	10 „ 7 „	0·00936
20 c. c. sol and 5 c. c. N/10 KCl	5 „ 14 „	10 „ 36 „	0·00974

Table VI.

Ceric hydroxide (hot) sol and HCl.
(Above sample of the sol.)

Temp. 25°

Water			0·00894
20 c. c. sol and 5 c. c. water	4 min. 56 sec.	9 min. 57 sec.	0·00918
20 c. c. sol and 5 c. c. N/500 HCl	4 „ 59 „	9 „ 59 „	0·00924
20 c. c. sol and 5 c. c. N/200 HCl	4 „ 54 „	9 „ 55 „	0·00907
20 c. c. sol and 5 c. c. N/100 HCl	5 „ 4 „	10 „ 17 „	0·00943
20 c. c. sol and 5 c. c. N/50 HCl	5 „ 9 „	10 „ 25 „	0·00958
20 c. c. sol and 5 c. c. N/10 HCl	5 „ 22 „	10 „ 54 „	0·00999

Merck's pure sodium tungstate was decomposed with equivalent amounts of HCl at the ordinary temperature and was dialysed :

TABLE VII.

Tungstic acid sol and KCl.

Concentration of the sol=3·08 gms. per litre.

(Different viscosity tubes used in the following experiments.)

Temp. 25°

Water			0·00894
20 c. c. sol and 5 c. c. water	4 min. 57 sec.	10 min. 27 sec.	0·00934
20 c. c. sol and 5 c. c. N/500 KCl	4 ,, 54 ,,	10 ,, 27 ,,	0·00927
20 c. c. sol and 5 c. c. N/100 KCl	4 ,, 54 ,,	10 ,, 26 ,,	0·00926
20 c. c. sol and 5 c. c. N/50 KCl	4 ,, 53 ,,	10 ,, 25 ,,	0·00924
20 c. c. sol and 5 c. c. N/10 KCl	4 ,, 52 ,,	10 ,, 25 ,,	0·00923
20 c. c. sol and 5 c. c. N/2 KCl	4 ,, 58 ,,	10 ,, 34 ,,	0·00939

TABLE VIII.

Benzopurpurin and KCl.

Concentration of the dye=7·02 gms. per litre.

Temp. 25°

Water			0·00894
20 c. c. dye and 5 c. c. water	4 min. 57 sec.	10 min. 15 sec.	0·00926
20 c. c. dye and 5 c. c. N/500 KCl	4 ,, 57 ,,	10 ,, 15 ,,	0·00926
20 c. c. dye and 5 c. c. N/100 KCl	4 ,, 57 ,,	10 ,, 14 ,,	0·00925
20 c. c. dye and 5 c. c. N/50 KCl	4 ,, 55 ,,	10 ,, 0 ,,	0·00916
20 c. c. dye and 5 c. c. N/20 KCl	4 ,, 57 ,,	10 ,, 5 ,,	0·00923
20 c. c. dye and 5 c. c. N/10 KCl	5 ,, 3 ,,	10 ,, 8 ,,	0·00941
20 c. c. dye and 5 c. c. N/1 KCl	5 ,, 20 ,,	11 ,, 23 ,,	0·01010

TABLE IX.

Benzopurpurin and HCl.

(The above solution of the dye.)

			Temp. 25°
Water			0·00894
20 c. c. dye and 5 c. c. water	4 min. 57 sec.	10 min. 15 sec.	0·00926
20 c. c. dye and 5 c. c. N/1000 HCl	4 „ 55 „	10 „ 10 „	0·00921
20 c. c. dye and 5 c. c. N/500 HCl	4 „ 52 „	10 „ 7 „	0·00913
20 c. c. dye and 5 c. c. N/100 HCl	4 „ 52 „	10 „ 4 „	0·00911

Hydrochloric acid was found to have a dissolving action on the sol.

TABLE X.

Silicic acid was obtained by the decomposition of $SiCl_4$ by water and dialysing it for about a month.

Silicic Acid sol and KCl.

Concentration of the sol = 12·075 gms. of SiO_2 per litre.

			Temp 30°
Water			0·00803
20 c. c. sol and 5 c. c. Water	4 min. 12 sec.	7 min. 11 sec.	0·00854
20 c. c. sol and 5 c. c. N/500 KCl	4 „ 11 „	7 „ 9 „	0·00852
20 c. c. sol and 5 c. c. N/100 KCl	4 „ 9 „	7 „ 8 „	0·00850
20 c. c. sol and 5 c. c. N/50 KCl	4 „ 22 „	7 „ 22 „	0·00883
20 c. c. sol and 5 c. c. N/10 KCl	4 „ 29 „	7 „ 45 „	0·00915
20 c. c. sol and 5 c. c. N/5 KCl	4 „ 43 „	8 „ 6 „	0·00960
20 c. c. sol and 5 c. c N/1 KCl	4 „ 27 „	7 „ 44 „	0·00910
20 c. c sol and 5 c. c. 1·69 N KCl	4 „ 14 „	7 „ 27 „	0·00870

Table XI.

Silicic Acid sol and HCl.

Concentration of the sol 12·075 gms. of SiO_2 per litre.

Temp. 30°

Water			0·00803
20 c. c. sol and 5 c. c. water	4 min. 19 sec.	7 min. 38 sec.	0·00888
20 c. c. sol and 5 c. c. N/2000 HCl	4 „ 18 „	7 „ 38 „	0·00886
20 c. c. sol and 5 c. c. N/1000 HCl	4 „ 17 „	7 „ 36 „	0·00884
20 c. c. sol and 5 c. c. N/500 HCl	5 „ 36 „	8 „ 38 „	0·01092
20 c. c. sol and 5 c. c. N/100 HCl	5 „ 43 „	8 „ 39 „	0·01109
20 c. c. sol and 5 c. c. N/50 HCl	5 „ 5 „	8 „ 23 „	0·01020
20 c. c. sol and 5 c. c. N/10 HCl	4 „ 44 „	8 „ 4 „	0·00961
20 c. c. sol and 5 c. c. N/1 HCl	4 „ 30 „	7 „ 52 „	0·00922

Table XII.

Gelatin supplied by Kahlbaum (Gold druck).

One per cent Gelatin solution and NaOH.—

With 0·1 c. c. of toluene.

Viscosity tube "C."

Temp. 30°

Water			0·00803
20 c. c. sol and 5 c. c. water	5 min. 25 sec.	9 min. 22 sec.	0·01106
20 c. c. sol and 5 c. c. N/1000 NaOH	5 „ 25 „	9 „ 17 „	0·01102
20 c. c. sol and 5 c. c. N/500 NaOH	5 „ 32 „	9 „ 33 „	0·01127
20 c. c. sol and 5 c. c. N/100 NaOH	6 „ 20 „	10 „ 59 „	0·01294
20 c. c. sol and 5 c. c. N/50 NaOH	7 „ 1 „	12 „ 7 „	0·01431
20 c. c. sol and 5 c. c. N/10 NaOH	6 „ 24 „	10 „ 53 „	0·01298
20 c. c. sol and 5 c. c. N/2·84 NaOH	5 „ 34 „	9 „ 30 „	0·01128
20 c. c. sol and 5 c. c. N NaOH	5 „ 20 „	9 „ 17 „	0·01099

TABLE XIII.

One per cent gelatin and KCl.

With 0·1 c. c. of toluene in 500 c. c. of the solution.

Freshly prepared gelatin solution.

VISCOSITY TUBE "C."

			Temp. 30°
Water			0·00803
29-3-27.			
20 c. c. sol and 5 c. c. water	4 min. 50 sec.	8 min. 17 sec.	0·00983
20 c. c. sol and 5 c. c. N/1000 KCl	4 „ 48 „	8 „ 18 „	0·00982
20 c. c. sol and 5 c. c. N/500 KCl	4 „ 49 „	8 „ 21 „	0·00984
20 c. c. sol and 5 c. c. N/100 KCl	4 „ 50 „	8 „ 22 „	0·00985
30-3-27.			
20 c. c. sol and 5 c. c. water	4 „ 58 „	9 „ 18 „	0·01043
20 c. c. sol and 5 c. c. N/50 KCl	4 „ 57 „	9 „ 15 „	0·01040
20 c. c. sol and 5 c. c. N/25 KCl	4 „ 58 „	9 „ 28 „	0·01047
20 c. c. sol and 5 c. c. N/5 KCl	5 „ 17 „	9 „ 41 „	0·01346

TABLE XIV.

One per cent Gelatin solution and HCl.

In order to avoid putrefaction 0·1 c. c. of pure toluene was added.

VISCOSITY TUBE "C."

			Temp. 30°
Water	4 min. 2 sec.	6 min. 31 sec.	0·00803
20 c. c. sol and 5 c. c. water	5 „ 25 „	9 „ 21 „	0·01105
20 c. c. sol and 5 c. c. N/1000 HCl	5 „ 20 „	9 „ 10 „	0·01085
20 c. c. sol and 5 c. c. N/200 HCl	5 „ 35 „	9 „ 26 „	0·01130
20 c. c. sol and 5 c. c. N/100 HCl	6 „ 10 „	10 „ 31 „	0·01252
20 c. c. sol and 5 c. c. N/50 HCl	7 „ 12 „	12 „ 33 „	0·01475
20 c. c. sol and 5 c. c. N/10 HCl	7 „ 31 „	12 „ 53 „	0·01530
20 c. c. sol and 5 c. c. N/0 672 HCl	5 „ 6 „	8 „ 38 „	0·01059

TABLE XV.

One per cent gelatin solution and $BaCl_2$.
With 0·1 c. c. of toluene in 500 c. c. of the solution.

VISCOSITY TUBE "C."

Temp. 30°

Water			0·00803
31-3-27.			
20 c. c. sol and 5 c. c. water	4 min. 59 sec.	9 min. 33 sec.	0·01055
20 c. c. sol and 5 c. c. N/1000 $BaCl_2$	4 „ 58 „	9 „ 34 „	0·01055
20 c. c. sol and 5 c. c. N/500 $BaCl_2$	4 „ 56 „	9 „ 28 „	0·01045
20 c. c sol and 5 c. c. N/100 $BaCl_2$	5 „ 1 „	9 „ 35 „	0·01062
1-4-27.			
20 c. c. sol and 5 c. c. water	4 „ 55 „	9 „ 22 „	0·01036
20 c. c. sol and 5 c. c. N/50 $BaCl_2$	5 „ 4 „	9 „ 32 „	0·01066
20 c. c. sol and 5 c. c. N/10 $BaCl_2$	5 „ 17 „	9 „ 47 „	0·01109

With all the above sols, experimental results show that in presence of small quantities of electrolytes the viscosity is decreased because of an increase in the charge on the sol. Results with thorium hydroxide show that in presence of thorium nitrate, the lowering of viscosity is greater than in presence of potassium iodide. This is certainly due to the fact that in presence of thorium nitrate the sol adsorbs thorium ion and the charge is increased to a greater extent than with potassium iodide.

The viscosity measurements with silicic acid sols in presence of electrolytes show that there is a very slight initial decrease, after this small decrease of viscosity it becomes greater than that of the original sol, and this increase in viscosity continues up to a limiting value when it begins to diminish again. These results can be explained from the following considerations:—The silicic acid sol prepared by us could not be coagulated by HCl

or KCl. We are of the opinion that in presence of increasing quantities of KCl or HCl the charge at first is slightly increased by the adsorption of ions carrying the same charge as the sol. With increasing quantities of electrolytes the charge becomes smaller and along with it the viscosity and hydration go on increasing. On increasing the concentration of the electrolyte further, it seems likely that there is a reversal of charge. Consequently there is a decrease in the viscosity. The experimental results obtained with gelatin are very interesting. In presence of small quantities of HCl, NaOH, KCl and $BaCl_2$ there is always a slight initial decrease in viscosity, due to a slight increase in charge. When the concentration of the electrolytes is increased, the viscosity goes on increasing with the concentration in the cases of KCl and $BaCl_2$; but in presence of NaOH and HCl with increasing concentrations of these substances the viscosity goes on increasing up to a limiting value and then it decreases. We are of the opinion that in presence of KCl and $BaCl_2$ the electric charge becomes less and less and hence the hydration and viscosity go on increasing, but with NaOH and HCl when the concentration of these substances is large, it seems likely that gelatin becomes really dissolved and hence the volume of the dispersed phase becomes less and the viscosity decreases.

THEORETICAL RESULTS.

We shall prove mathematically that the increase in the charge on the colloid particles leads to a decrease in the surface of the particles and consequently the amount of hydration is also decreased.

The assumptions that we have made in the mathematical treatment are:—

(1) the particles of any colloid are generally ellipsoidal; for due to the Brownian movement the form

of the colloid particles cannot easily have any corners, since collisions will tend to round up the edges. As a result of this movement we may expect that the particles in general are likely to be ellipsoids and under ideal conditions, may be even spherical;

(2) the ellipsoids are imagined to be formed by revolution about the major axis 'a' and the minor axis 'b.'

Starting with these assumptions let us calculate what will be the tendency of change of form of any particle if a positive charge is given to it, and to do so we will calculate the mechanical force along the major and any of the minor axes.

It is well-known that in an ellipsoid the distribution of electric charge is such that the surface density 'σ' at any point is proportional to the perpendicular 'p' from the centre on the tangent plane at that point;

$$K_1 . p = \sigma \quad \ldots \text{(i)}$$

Let A B C be an ellipsoid and the three axes be OX, OY and OZ; OX being the major axis (Fig. I).

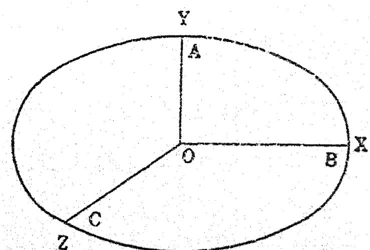


Fig. I.

Cutting the ellipsoid in the plane of OY and OZ the cross-section will be a circle. If we imagine a slice PQ to be cut as shaded (in Fig. II) of thickness dz, then the slice will be an elliptic plate of thickness dz and the sides inclined at an angle θ equal to POZ (Fig. II). The minor axis of this elliptic plate will be equal to b sin θ and the major axis can be calculated from the equation of ellipse and will be a sin θ.

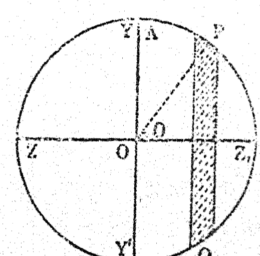


Fig. II.

Let us consider the elliptic plate and calculate the force due to the electric charge given to it. This plate is of thickness dz and if we measure s along the edge then any element of area will be represented by :—

$$dA = ds.\ dz \qquad \dots \qquad \dots \quad \text{(ii)}$$

Now the mechanical force due to electric charge is

$$2\pi\ \sigma^2.\ dA.$$

(where σ is the density of charge and dA is the area).

Since the edges are inclined at an angle θ, the component of the mechanical force in the plane of the slice is clearly :—

$$2\pi\ \sigma^2.\ dA.\ \sin\ \theta.$$

Resolving this along the minor axis, that is perpendicular to the axis of revolution of the ellipsoid we get:—

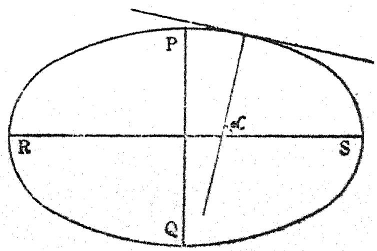


Fig. III.

$$2\pi\ \sigma^2\ dA.\ \sin\theta\ \sin\alpha \qquad \dots \qquad \dots \quad \text{(iii)}$$

where α is the angle which the normal at that point makes with major axis. Combining equation (iii) with (ii) we get :—

$$2\pi\ \sigma^2.\ ds.\ dz.\ \sin\theta.\ \sin\ \alpha \quad \dots \quad \text{(iv)}$$

Substituting the value of σ as given in equation (i) in equation (iv) we get the vertical component of the mechanical force :—

$$2\pi\ K_1^2\ p^2.\ ds.\ dz.\ \sin\theta.\ \sin\alpha$$

$$= 2\pi\ K_1^2\ p^2.\frac{ds}{dx}.dz\ \sin\alpha\ \sin\theta\ .\ dx$$

$$= 2\pi\ K_1^2\ p^2.\ dx\ .\ dz.\ \sin\ \theta \qquad \dots \qquad \dots \quad \text{(v)}$$

If we represent a_1, and b_1, as the major and **minor** axes of the elliptic plate then (v) becomes :—

$$2\pi K_1^2 \quad \frac{a^4 b_1^4}{(x^2 b_1^4 + y^2 a_1^4)}\ .\ dx\ \sin\theta\ .\ dz$$

$$= 2\pi K_1^2 \frac{a_1^4\ b_1^2 .\ dx}{a_1^4 - x^2\ (a_1^2 - b_1^2)} \sin \theta .\ dz$$

$$= K_2 b_1^2 \left\{ \frac{dx}{1 - \frac{x^2 (a_1^2 - b_1^2)}{a_1^4}} \right\} \sin \theta\ dz \qquad \ldots \text{(vi)}$$

where K_2 is equal to $(2\pi\ K_1{}^2$

This is equal to

$$\frac{K_2 b_1{}^2}{2} \left\{ \frac{dx}{1 + \frac{x\sqrt{a_1{}^2 - b_1{}^2}}{a_1{}^2}} + \frac{dx}{1 - \frac{x\sqrt{a_1{}^2 - b_1{}^2}}{a_1{}^2}} \right\} \sin \theta\, dz \ldots \text{(vii)}$$

To find the vertical component of the force in the semi-ellipse RPS (Fig. III), we have to integrate the above expression (vii) limits of x lying between $-a_1$ and $+a_1$. We have the component equal to :—

$$\frac{K_2 b_1{}^2}{2} \cdot \sin \theta\, dz \int_{x=-a_1}^{x=+a_1} \left\{ \frac{dx}{1 + \frac{x\sqrt{a_1{}^2 - b_1{}^2}}{a_1{}^2}} + \frac{dx}{1 - \frac{x\sqrt{a_1{}^2 - b_1{}^2}}{a_1{}^2}} \right\}$$

$$= K_2 b_1{}^2 \sin \theta\ dz.\ \log \frac{1 + \frac{a_1\sqrt{a_1{}^2 - b_1{}^2}}{a_1{}^2}}{1 - a_1 \frac{\sqrt{a_1{}^2 - b_1{}^2}}{a_1{}^2}} \times \frac{a_1{}^2}{\sqrt{a_1 - b_1{}^2}}$$

$$= K_2 \frac{a_1{}^2 b_1{}^2}{\sqrt{a_1{}^2 - b_1{}^2}} .\ \sin \theta\, dz.\ \log \frac{1 + \sqrt{1 - \frac{b_1{}^2}{a_1{}^2}}}{1 - \sqrt{1 - \frac{b_1{}^2}{a_1{}^2}}} \qquad \ldots \quad \ldots \text{(viii)}$$

This is the total vertical component of the mechanical force due to the electric charge on the edges of the elliptic plate of thickness dz and the edges being inclined at an angle θ.

To find the vertical component of the force on the whole hemi-ellipsoidal surface we have to integrate the expression (viii) the limits of z lying between $-$b and $+b$ (cf. Fig. II).

We have the whole vertical component on the surface RPS (Fig. III).

$$=K_2 \int_{z=-b}^{z=+b} \frac{a_1^2 b_1^2}{\sqrt{a_1^2-b_1^2}} \,.\, \sin \theta \log \frac{1+\sqrt{1-\frac{b_1^2}{a_1^2}}}{1-\sqrt{1-\frac{b_1^2}{a_1^2}}}\, dz$$

It has been shown that $a_1 = a \sin \theta$, and $b_1 = b \sin \theta$, where a and b are the major and minor axes of the ellipsoid and θ the angle subtended by the semi-minor axis of the elliptic plate at the centre of the ellipsoid.

Then the whole vertical component on the hemi-ellipsoid is equal to :—

$$K_2 \int_{z=-b}^{z=b} \frac{a^2 b^2 \sin^4 \theta}{\sqrt{a^2-b^2}} \log \frac{1+\sqrt{1-\frac{b_1^2}{a_1^2}}}{1-\sqrt{1-\frac{b_1^2}{a_1^2}}}\, dz.$$

Since $dz = b\, d\theta \sin \theta$ (Fig. II)

$$=K_2 \frac{a^2 b^2}{\sqrt{a^2-b^2}} \log \frac{1+\sqrt{1-\frac{b^2}{a^2}}}{1-\sqrt{1-\frac{b^2}{a^2}}} \,.\, b \int_0^{\pi} \sin^5 \theta \,.\, d\theta$$

$$=K_2 \frac{a^2 b^2}{\sqrt{a^2-b^2}} \log \frac{1+\sqrt{1-\frac{b^2}{a^2}}}{1-\sqrt{1-\frac{b^2}{a^2}}} \,.\, b.\, 2. \int_0^{\pi/2} \sin^5 \theta \,.\, d\theta \,.$$

$$=K_2 \frac{a^2 b^3}{\sqrt{a^2-b^2}} \log \frac{1+\sqrt{1-\frac{b^2}{a^2}}}{1-\sqrt{1-\frac{b^2}{a^2}}}\; 2 \,.\, \frac{8}{15} \quad \ldots \quad \ldots \text{(ix)}$$

In order to find the horizontal component of the mechanical forces on the half-ellipsoid cut by the plane YOZ (Fig. I) we put a_1 for b_1 and b_1 for a_1 in the expression (vi)

then the horizontal component of the force on any element of area

$$= K_2\, a_1^2 \left[\frac{dx}{1+\dfrac{x^2(a_1^2-b_1^2)}{b_1^4}} \right] \operatorname{Sin}\theta\,.\,dz$$

To find the horizontal component on the semi-ellipse PSQ (Fig. II) we have to integrate the above expression within limits of x lying between $-b_1$ and b_1. The component therefore

$$= K_2\, a_1^2 \operatorname{Sin}\theta\; dz \int_{x=-b}^{x=+b} \frac{dx}{1+\dfrac{(x^2 a_2^1-b_1^2)}{b_1^4}}$$

$$= K_2 a_1^2 \operatorname{Sin}\theta\,.\,dz \left[\tan^{-1} x\frac{\sqrt{a_1^2-b_1^2}}{b_1^2} \right]_{-b}^{+b} \cdot \frac{b_1^2}{\sqrt{a_1^2-b_1^2}}$$

$$= 2K_2 \frac{a_1^2 b_1^2}{\sqrt{a_1^2-b_1^2}} \cdot \operatorname{Sin}\theta \;.\; \tan^{-1}\frac{\sqrt{a_1^2-b_1^2}}{b_1}\; dz$$

$$= 2K_2 \frac{a^2 b^2 dz}{\sqrt{a^2-b^2}} \cdot \operatorname{Sin}^4\theta \;.\; \tan^{-1}\sqrt{\frac{a^2}{b^2}-1} \;\ldots \qquad \text{(x)}$$

Since $a_1 = a \operatorname{Sin}\theta$ and $b\theta = b \operatorname{Sin}\theta$

The whole horizontal component on the hemi-ellipsoid cut by the plane YOZ

$$= 2K_2 \frac{a^2 b^2}{\sqrt{a^2-b^2}} \,.\, \tan^{-1} \sqrt{\frac{a^2}{b^2}-1}\,. \int_{z=-b}^{z=+b} \operatorname{Sin}^4\theta\,.\,dz$$

Since $dz = bd\theta \operatorname{Sin}\theta$

$$= 2K_2 \frac{a^2 b^2}{\sqrt{a^2-b^2}} \tan^{-1}\sqrt{\frac{a^2}{b^2}-1} \int_0^{\pi} b\,.\operatorname{Sin}^5\theta\,.\,d\theta.$$

$$= {}^{4}K_2 \frac{a^2 b^3}{\sqrt{a^2 - b^2}} \tan^{-1}\sqrt{\frac{a^2}{b^2} - 1} \times \frac{8}{15} \quad \ldots \quad \ldots \text{(xi)}$$

Putting K for $2 \dfrac{a^2 b^3}{\sqrt{a^2 - b^2}} \times \dfrac{8}{15} \cdot K_2$

we have the perpendicular force tending to increase the minor axis (from ix) of the ellipsoid

$$= K \log \frac{1 + \sqrt{1 - \frac{b^2}{a^2}}}{1 - \sqrt{1 - \frac{b^2}{a^2}}} \quad \ldots \quad \ldots \quad \ldots \quad \text{(xii)}$$

and the lateral force tending to increase the major axis of the ellipsoid (from xi)

$$= 2K \tan^{-1} \sqrt{\frac{a^2}{b^2} - 1} \quad \ldots \quad \ldots \quad \ldots \quad \text{(xiii)}$$

The following table gives the perpendicular force along the minor axis and the lateral force along the major axis of the ellipsoid for different values of $\frac{a^2}{b^2}$

$\frac{a^2}{b^2}$	Vertical force Eq. (xii) x k	Lateral force Eq. (xiii) x k	Difference x k
1·000	0·000*	0·000	0·000
1·010	0·202	0·199	0·003
1·125	0·692	1·230	0·013
1·500	1·297	2·093	0·067
1·800	1·608	1·356	0·252
4·000	2·631	2·039	0·538
∞	∞	3·142	∞

* The absolute values will be finite since k tends to ∞ but the two values, one of the vertical force and the other of lateral, will be equal to one another.

If we represent $\frac{a^2}{b^2}$ along the X axis and the forces along the Y axis we get the graph as shown, in which Curve I gives the vertical and Curve II the horizontal component of force.

It will be seen that Curve I always lies above Curve II.

The same fact follows directly from expressions (xii) and (xiii) by differentiating with respect to x, *i.e.*, $\frac{a^2}{b^2}$

The inclination $\frac{dy}{dx}$ of Curve I

$$=\frac{k\sqrt{x}}{x\sqrt{x-1}} \quad \ldots \quad \ldots \quad \ldots \quad \text{(xiv)}$$

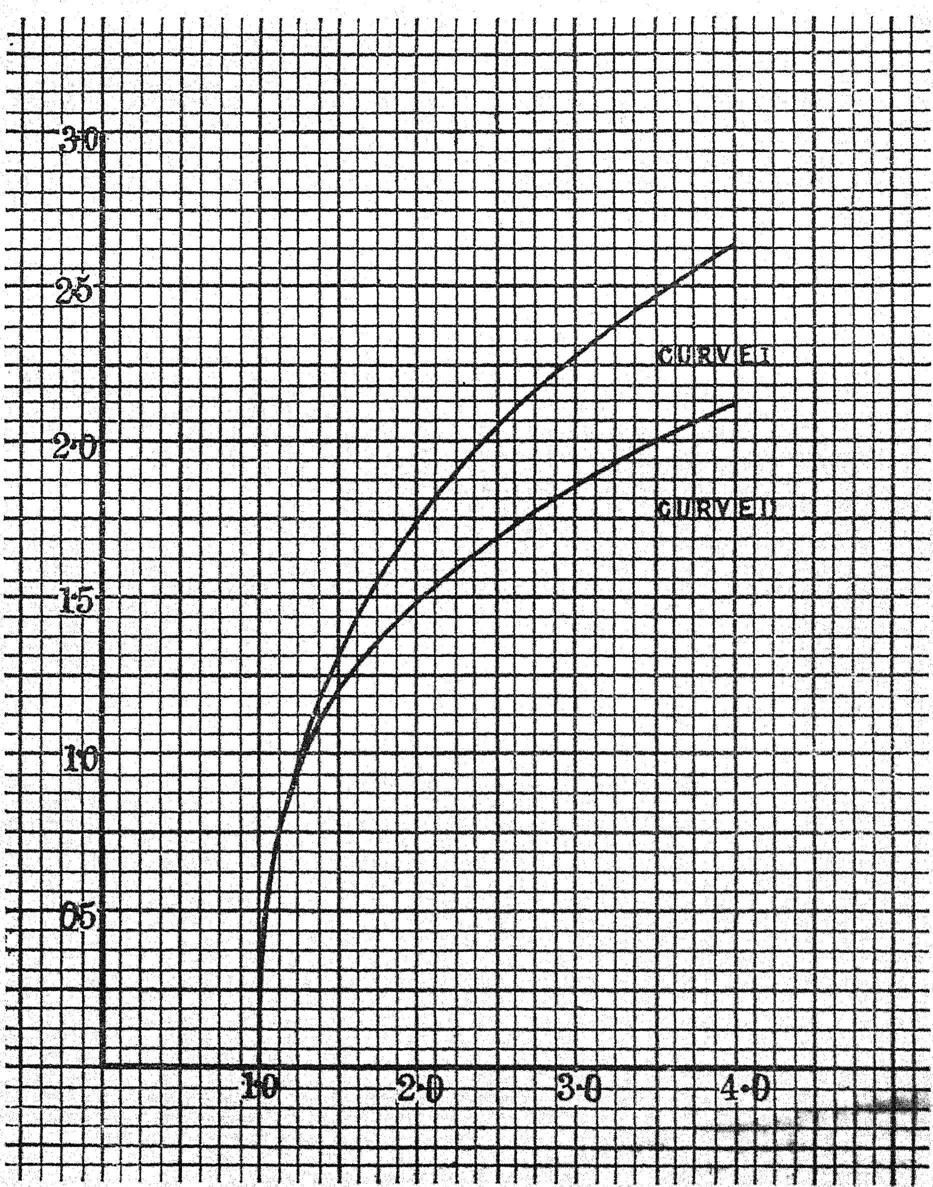
and that of Curve II

$$=\frac{K}{x\sqrt{x-1}} \quad \ldots \quad \ldots \quad \ldots \quad \text{(xv)}$$

Since $\frac{a^2}{b^2}$, *i.e.*, x is always greater than 1, the expression (xiv) is always greater than (xv). Since both curves cut on the X axis, *i.e.*, $y=0$, Curve I should always be above the Curve II. (See page 283.)

Thus we see that in an ellipsoid the force tending to increase the minor axis is much greater than the force tending to increase the major axis. Hence the ellipsoid will tend to become spherical when an increased charge is given to it. Due to rigidity of the particles of the colloid the volume remains very nearly the same so the surface tends to minimise because the sphere has the least surface for any particular volume, and along with it the hydration also decreases. This effect will be more pronounced, the greater the charge on the colloid particles. With decrease of hydration the viscosity decreases. Thus we see that the initial decrease of viscosity of a colloid by the addition of an electrolyte is due to the adsorption of the ion carrying the same charge as the colloid, and

this increased charge tends to round up the particles thus diminishing the free surface, hydration, and viscosity. When the amount of electrolyte is greater the charge is progressively neutralised and the reverse changes take place.



It is well-known that the Einstein formula

$$\eta_s = \eta_m \quad (1 + 2{\cdot}5\theta)$$

assumes that (1) the particles of the colloid are rigid, (2) the number of particles is small, (3) the particles are large in comparison with the sphere of molecular attraction and (4) the particles are spherical.

According to Einstein the viscosity of any sol will depend upon the volume of the dispersed phase only; in other words, the question of specificity will not arise but from our experience we know that the viscosity depends upon the nature of the sol.

From our calculations given in the foregoing pages it will be clear that the lateral and the vertical forces nullify each other when the particles are spherical. In other words, when the colloid particles are spherical the increase in the charge should not affect the surface, hydration, and the viscosity of a colloid. However, from our experimental results with numerous sols we observe that there is always a change of viscosity with the change in the electric charge on the particles. Consequently it appears that the ideal case where the colloid particles are spherical, as has been assumed by Einstein, is hardly met with. Hence it follows that most colloids are more or less non-spherical, because usually there is a decrease of viscosity of a colloid on increasing the charge. It will be interesting to note in this connection that substances like vanadium pentoxide, gelatin, soaps, etc., which are known to form non-spherical particles, have high viscosity. In a recent communication we have shown that ceric hydroxide sol prepared in the cold has a high viscosity. It will be interesting to investigate whether this sol forms non-spherical particles or not. In a recent communication* Freundlich concluded that a sol of benzopurpurin consists of non-spherical particles.

* Colloid Chemistry, Symposium, Vol. II, 1925, p. 46.

We have carefully determined the viscosity of this sol but our experimental results show that the viscosity is not high as compared to other sols.

SUMMARY.

(1) Viscosity measurements have been carried on with sols of thorium hydroxide prepared in the hot and cold conditions, ceric hydroxide prepared in the hot condition, tungstic acid, benzopurpurin, and silicic acid prepared in the hot and cold conditions in presence and in absence of different electrolytes.

(2) With all the sols there is a decrease of viscosity on the addition of small quantities of electrolytes. With thorium hydroxide sol experimental results show that there is a greater lowering of viscosity in presence of thorium nitrate than in presence of potassium iodide, due to a greater increase of charge in case of thorium nitrate than in potassium iodide.

(3) The viscosity of silicic acid after a slight fall goes on increasing up to a maximum limit, then it decreases with increasing concentration of the added electrolyte. An explanation of this peculiar behaviour has been advanced.

(4) With gelatin (1 %) in presence of KCl and $BaCl_2$ the viscosity goes on increasing with increasing concentration of the electrolyte, but with NaOH and HCl with increasing concentrations of these substances the viscosity goes on increasing up to a limiting value and then it decreases. This peculiar behaviour has also been explained.

(5) It has been deduced mathematically that when the charge on a colloid particle is increased the surface tends to become less. Along with the decrease in the surface, the hydration and viscosity also diminish. This deduction has been corroborated by our experiment with numerous sols.

ZINC OXIDE AS A GENERAL SENSITISER FOR PHOTOCHEMICAL REACTIONS

BY

A. K. BHATTACHARYA AND N. R. DHAR.

If a system is not sensitive to light, it suffices at times to add to it a small quantity of another substance in order to make it sensitive to the action of rays absorbed by that substance ; this action is known as *photochemical sensitisation* and the substance, which absorbs the light and provokes the reaction without apparently taking part in it, is called a *sensitiser*.

There is a class of photo sensitisation in which a system which is chemically influenced by certain radiations is rendered sensitive to rays of another wave-length by a substance which absorbs these rays. Several years ago Weigert (1) showed that ozone which is decomposed by ultra-violet rays but not much by visible light is decomposed readily under the action of blue light when mixed with chlorine. Similarly in a foregoing paper (2) we have shown that the decomposition of Fehling's solution, Cupri-ammonium oxalate, Eder's mixture ($HgCl_2$) and $(NH_4)_2(C_2O_4)$, a mixture of mercuric chloride and a tartrate, etc., can be markedly accelerated by ferric or uranyl salts under the influence of sunlight. Moreover, Cosin, Chlorophyll and several other substances have been used as sensitisers.

In a foregoing paper we have explained photo sensitisation from the point of view of the activation of molecules from the Franck-Carro point of view. For example, in the sensitisation of the decomposition of ozone in presence of chlorine, we can assume that by the absorption of blue light, the chlorine molecules get activated and such chlorine molecules are

instrumental in bringing about the decomposition of ozone or the photochemical combination of hydrogen and oxygen in sunlight as observed by Norrish. Similarly, by the absorption of visible light, a molecule of chlorophyll is activated and this active molecule induces the chemical change between carbon dioxide and water-vapour in plants.

In this investigation we have carried on numerous experiments with several photochemical reactions in presence of finely divided zinc oxide as a sensitiser. We have observed that zinc oxide behaves as a very powerful sensitiser for several photochemical reactions.

In previous papers we have proved that the velocity of sugar inversion in presence of acids is markedly accelerated by light and that inversion of cane-sugar takes place in sunlight even in the absence of acids. We have now observed that sugar inversion and hydrolysis of maltose can be markedly accelerated by sunlight in presence of zinc oxide as a sensitiser.

The following reactions have been found to be sensitised by zinc oxide in presence of sunlight:—

(1) Decomposition of Fehling's solution, (2) Decomposition of Cupri-ammonium Oxalate, (3) Formation of reducing sugars from Formaldehyde, (4) Formation of reducing sugars from Glycerol, (5) Oxidation of Methyl or Ethyl or Propyl alcohol to the respective aldehyde by air, (6) Formation of metallic gold from Gold chloride, (7) Formation of metallic platinum from Platinic chloride, (8) Oxidation of Quinine Sulphate by Chromic acid, (9) Oxidation of Potassium Iodide by Potassium persulphate, (10) Oxidation of Sodium Citrate by Iodine, (11) Oxidation of Oxalic acid by Iodine, (12) Oxidation of Potassium Tartrate by Iodine, (13) Hydrolysis of Maltose, (14) Oxidation of Sodium formate by Iodine, (15) Oxidation of Iodoform, (16) Oxidation of Potassium Tartrate by Bromine, (17) Oxidation of Sodium Nitrite by Iodine, (18) Oxidation of Hydroxylamine Hydrochloride by Iodine,

(19) Oxidation of Hydrazine Hydrochloride by Iodine, (20) Oxidation of Sodium formate by Mercuric chloride, (21) Oxidation of Sodium Sulphite by Mercuric chloride, (22) Oxidation of Hydrazine Hydrochloride by Mercuric chloride, (23) Oxidation of $(NH_4)_2\ (C_2O_4)$ by Mercuric chloride, (24) Oxidation of Potassium Tartrate and Mercuric chloride, (25) Oxidation of Sodium Malate and Mercuric chloride, (26) Oxidation of Potassium citrate and Mercuric chloride, (27) Oxidation of Sodium Lactate and Mercuric chloride, (28) Oxidation of Sodium Dichloracetate and Mercuric chloride, (29) Decomposition of Mercuric Oxide, (30) Decomposition of $KMnO_4$, (31) Decomposition of Potassium oxalate.

The following reactions are also sensitized by substances other than ZnO but in all the reactions ZnO is the best sensitiser.

(1) Potassium Tartrate and $HgCl_2$—acceleration by Ferric and Ferrous chloride, $KMnO_4$ uranium nitrate and Al_2O_3.

(2) Sodium formate and $HgCl_2$—in presence of Al_2O_3 and MnO_2.

(3) Ammonium Malonate+$HgCl_2$—in presence of Al_2O_3.

(4) Sodium Malate+$HgCl_2$—in presence of Al_2O_3.

(5) Hydrazine Hydrochloride+$HgCl_2$—in presence of Al_2O_3 and Erythrosin.

The bleaching of a number of dyes has been investigated in sunlight in presence of ZnO.

To determine the extinction coefficient the dye was kept in a glass cell and placed before a Nutting spectrophotometer and the absorption was read on the density scale of the instrument. Knowing the thicknes of the cell, the extinction coefficient was calculated by the formula :—

$$\text{Extinction coeff.} = \frac{\text{Density Reading}}{\text{Thickness}}$$

10 c. c. taken in a glass dish. ·1 gm. of ZnO was added.

Number.	Dyes.	Region in Å Units.	Time.		Extinction Coeff. Unexposed (Dark).	Extinction Coeff. Exposed (Sunlight.)	Extinction Coeff. Exposed with ZnO (Sunlight).
			Hr.	Min.			
A	**Blue Violet and Green.**						
1	Crystal Violet Do. + ZnO	5560	1	30	2·753	2·624	·130
2	Methyline Blue Do. + ZnO	5560	1	0	1·065	·805	Bleached
3	Ethyl Green Do. + ZnO	5560	1	30	2·233	2·104	·130
4	Nile Blue Do. + ZnO	5560	1	0	1·065	1·064	Bleached
5	Azolitmin Do. + ZnO	5840	1	0	1·351	1·299	·005
6	Aniline Blue Do. + ZnO	5880	1	0	5·558	2·442	·397
7	Nigrosin Do. + ZnO	5840	1	0	1·299	1·299	·130
8	Genatian Violet Do. + ZnO	5700	1	0	1·584	1·065	·005
9	Malachite Green Do. + ZnO	5840	1	0	2·078	2·078	·312
10	Methyl Violet Do. + ZnO	5040	1	0	·805	·727	·104
11	Indigo Carmine Do. + ZnO	5040	1	0	·779	·779	·156

Number.	Dyes.	Region in A° Units.	Time. Hr. Min.	Extinction Coeff. Unexposed (Dark).	Extinction Coeff. Exposed (Sunlight).	Extinction Coeff. Exposed with ZnO (Sunlight.)
12	Water Blue Do. + ZnO	5589	1 0	1·091	1·040	·935
13	Alizarin Blue Do. + ZnO	5240	1 0	4·571*	4·831*	4·468*
14	Cupric Blue Do. + ZnO	5360	1 0	1·351	1·247	·935
15	Aniline Victorian Blue Do. + ZnO	5240	1 0	2·857	2·337	1·091
B.	**Fluorescent Dyes.**					
16	Eosin Do. + ZnO	5520	1 45	1·506	·571	·026
17	Fluorescein Do. + ZnO	5200	1 45	1·114	·649	·104
18	Rhodamine Do. + ZnO	5640	1 45	1·974	1·948	·519
19	Erythrosine Do. + ZnO	5480	1 45	3·636	2·208	·727
20	Uranine Do. + ZnO	5360	1 45	1·117	1·065	·779
21	Pronine G. Do. + ZnO	5360	1 0	2·441	2·208	2·078
22	Acridine Red Do. + ZnO	5360	1 0	1·714	1·688	·883
C.	**Red, Yellow & Orange.**					
23	Rose Bengale Do. + ZnO	5920	2 30	1·506	1·351	1·273
24	Congo Red Do. + ZnO	5840	2 30	1·558	1·548	·987

Number.	Dyes.	Region in A° Units.	Time. Hr.	Min.	Extinction Coeff. Unexposed (Dark).	Extinction Coeff. Exposed (Sunlight).	Extinction Coeff. Exposed with ZnO (Sunlight).
25	Aurine Do. + ZnO	5680	1	0	1·247	·935	·519
26	Magenta Do. + ZnO	5840	1	0	1·818	1·901	·753
27	Aniline Red Do. + ZnO	6160	1	0	2·208	1·091	1·040
28	Aniline Yellow Do. + ZnO	5120	1	0	2·078	1·974	·312*
29	Auramine Do. + ZnO	4880	1	0	1·040	·984*	·984*
30	Methyl Orange Do. + ZnO	5040	1	0	2·727*	2·857*	1·948
31	Purpurin Do. + ZnO	5589	1	0	1·402	·883	·364
32	Tropaeolin Do. + ZnO	5560	1	0	·779	·727	·519
33	Aniline Scarlet Do. + ZnO	5720	1	0	1·298	1·194	1·091
34	Theonine Grubber Do. ZnO	5360	1	0	1·039	·984	·883
35	Thioflavain Do. + ZnO	5360	1	0	4·675	1·558	1·039
36	Corcus Red Do. + ZnO	5240	1	0	1·091	·678	·623
37	Rosaniline Do. + ZnO	5240	1	0	1·195	1·039*	2·337*
38	Acridine Orange Do. + ZnO	5360	1	0	2·340	2·078	1·948
39	Acridine Yellow Do. + ZnO	5360	1	0	1·299	1·195	·987
40	Aesculin Do. + ZnO	5360	1	0	649	·597	·416

In diffused light there was no change in the colour of the dyes with zinc oxide. The bleaching of the dyes was noticeable in a short time when the solutions were exposed to sunlight with zinc oxide.

As a general behaviour it was found that the dyes which absorb light of longer wave-lengths are much accelerated in bleaching in sunlight by zinc oxide. The next in order comes the fluorescent dyes which also absorb light of longer wave-lengths, and lastly are the dyes of red, orange and yellow type which absorb light of shorter wave-lengths. There are only very few exceptions to the above generalisation which might be due to impurities.

In recent papers Baur[1] and co-workers have investigated the sensitising influence of zinc oxide on the photochemical decomposition of an aqueous solution of silver nitrate and methylene blue in absence of air.

In the case of the decomposition of silver nitrate, Baur and Parret represented the process schemetically as follows :—

$$\mathrm{ZnO}\left\{\begin{array}{lllll} \mathrm{O} & \mathrm{Ag\,NO_3} & \mathrm{OH'} & \text{Peroxide} & \text{Oxygen} \\ \mathrm{O} & \mathrm{Ag^{\circ}} & \mathrm{Ag^{\circ}} & & \end{array}\right.$$

We are of the opinion that this scheme of Baur is unsatisfactory because there is no experimental evidence in support of the above views, and the decomposition of silver nitrate can be easily understood from the following considerations. It is well-known that sols of heavy metals like silver, gold, platinum, etc., have a tendency to decompose and in presence of light solutions of these salts decompose readily. In presence of zinc oxide this decomposition tendency of silver nitrate is increased.

We are of opinion that in presence of light the molecules of zinc oxide absorb the radiation and become activated. The activated molecules of zinc oxide come in contact with the molecules of silver nitrate and activate them

[1] Helv. Chim. Acta 7, 910 (1924).

by the transference of energy from the molecules of zinc oxide to those of silver nitrate. The decomposition of silver nitrate takes place according to the following equation :—

$$2AgNO_3 + H_2O = 2\,Ag + 2HNO_3.$$

In addition to the sensitising effect zinc oxide has also the function of neutralising the nitric acid which is set free and thus helps the decomposition of silver nitrate. We have observed that in presence of calcium carbonate, strontium carbonate, etc., which also neutralise the free nitric acid, solutions of silver nitrate appreciably decompose in sunlight, but the effect of calcium carbonate, or strontium carbonate is not as great as zinc oxide which also acts as a marked photochemical sensitiser.

In a recent paper Chakravarti and Dhar have shown that solutions of dyes are unstable in presence of light and they can be readily oxidised or reduced under suitable conditions. We have shown that in presence of air several dye solutions are readily oxidised in presence of light and in this paper we have shown that this oxidation of dyes is markedly accelerated by zinc oxide. Moreover in the same paper Chakravarti and Dhar proved that the solutions of dyes also can decompose in presence of strong ultra-violet or sunlight just as solutions of potassium permanganate, potassium persulphate or ammonium nitrite in presence of strong light.

In this paper we have proved that the decomposition of potassium permanganate, potassium persulphate, etc., in sunlight is accelerated by zinc oxide.

Baur[1] has represented the photolysis of methylene blue in presence of zinc oxide when air is not present in the following way :—

$$ZnO \left\{ \begin{array}{lll} O & \text{methylene blue} & \text{products of oxidation.} \\ O & \text{methylene blue} & \text{leuco compounds.} \end{array} \right.$$

[1] Faraday Society Discussion, October, 1925, p. 629.

We are, however, of the opinion that these dyes which are unstable substances decompose in sunlight in the same way as the solution of potassium permanganate decomposes in sunlight. It is likely that the decomposition of dyes can in some cases be compared to the decomposition of nitrous acid, hypophosphorous acid, phosphorous acid, etc., according to the following equations :

$$3HNO_2 = HNO_3 + 2NO + H_2O$$
$$4H_3PO_3 = 3H_3PO_4 + PH_3$$
$$2H_3PO_2 = H_3PO_4 + PH_3$$

The photochemical decomposition of nitrogen pentoxide has been found by Daniels and Johnston[1] to be accelerated in visible light in presence of nitrogen dioxide. We are of opinion that nitrogen dioxide acts as a sensitiser in the photochemical decomposition of nitrogen pentoxide, just as chlorine sensitises the photochemical decomposition of ozone.

Further work on photosensitisation and photo-inhibition is in progress in these laboratories.

[1] J. Amer. Chem. Soc., *43*, 53, 72 (1921).

ON THE THEORY OF PEPTISATION OF METALLIC HYDROXIDES IN PRESENCE OF NON-ELETROLYTES

BY

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Though the peptisation of metallic hydroxides and salts by ions and electrolytes is generally known and the theory underlying the process comparatively well understood,[1] the direct peptisation of substances by non-electrolytes is not known. A considerable emphasis has however been given to many cases where the presence of non-electrolytes prevents or inhibits the formation of a visible precipitate. Bancroft[2] mentions several such. Thus a concentrated solution of sugar in water will prevent the precipitation of calcium silicate,[3] silver chromate and silver chloride,[4] and of lime and of the hydrous oxides of copper,[5] uranium and iron.[6] Grimaux[7] showed that glycerine prevents the precipitation of hydrous ferric oxide by caustic potash. Experiments of similar nature were done by the present writer in a previous paper.[8] A quantitative work in this line is that of Kuhn and Pirsch.[9] Thus though many stray cases have become known, no progress seems to have been made to give a general explanation of the peptisation

[1] Cf. Lottermoser: Jour. Prakt. (2) Chem. *60*, 341 (1903); *72*, 39 (1905); Zeit physik chem., *62*, 371 (1908).
[2] W. D. Bancroft: 2nd B.A. Report on Colloid Chem., p. 2 (1918).
[3] Weisberg: Bull. Soc. Chem. Paris (3), *15*, 1097 (1896).
[4] Lobry de Bruyn: Ber. deutsch Chem. Ges., *35*, 3079 (1902).
[5] Graham: Jour. Chem. Soc., *15*, 253 (1862).
[6] Riffard: Compt. rend. *77*, 1103 (1873).
[7] Compt. rend. *98*, 1485, 1540 (1884).
[8] Kolloid zeit. *33*, 193 (1923).
[9] Kolloid zeit. (Zsigmondy Festschr), *36*, 310 (1925).

observed. The object of the present paper is to discuss some experimental results with a view to the formulation of a general theory.

According to Freundlich,[1] all adsorption is accompanied by a lowering of the surface tension of the adsorbent, and Bancroft[2] therefore considers that the adsorption of any substance will tend to peptise a precipitate. On this view we can assume that the non-electrolytes which are adsorbed by the colloid particles keep them peptised owing to their effect on the surface tension of the solid phase. That this effect cannot be the sole cause of peptisation is evident from the fact that a definite amount of acid or alkali is necessary for peptisation of certain hydroxides as shown in recent papers[3] even in presence of the non-electrolytes. The experimental results with iron and chromium hydroxides were given in that paper. In the following Table I a set of results is shown on the peptisation of copper hydroxide in presence of sucrose.

TABLE I.

Total volume = 15 c.c.

Amount of Cu. milli-gram atom peptised.	Millimoles of sucrose necessary to prevent the formation of a precipitate.		
	NaOH=2 millimoles.	NaOH=3 millimoles.	NaOH=5 millimoles.
0·125	0·05	...	0·04
0·250	0·14	0·1	0·1
0·375	0·20	0·19	0·175
0·500	0·31	0·25	0·23
0·625	0·85	0·34	0·32
0·750	> 8·0	0·64	0·55

[1] Kapillarchemie., 154 (1909). [2] Jour. Phys. Chem., *20*, 85 (1916).
[3] Mehrotra and Sen: Kolloid zeit. *42*, 35 (1927); Jour. Ind. Chem. Soc., *4*, 117 (1927); Sen: *ibid.*, *4*, 131 (1927).

On peptisation, the solution containing copper hydroxide is clear both in reflected and transmitted light and shows a blue colour. From Table I it will be observed that the amount of alkali present in the solution has a decided effect on the amount of sugar necessary for inhibiting the formation of a visible precipitate. When the concentration of copper peptised is low, this effect is not prominent because the amount of alkali present is in large excess in every case. In the case of higher concentrations of copper, however, the effect is easily perceived. Thus when the amount of copper peptised is 0·75 milligram atoms, then 0·55 millimole of sucrose is sufficient for the inhibition of the precipitation when the amount of alkali is 5 millimoles, whereas in presence of 2 millimoles of alkali, even 8 millimoles of sucrose are insufficient for peptisation. This shows that a minimum excess of alkali is necessary for the peptisation of copper hydroxide into a blue sol in presence of non-electrolytes like sugar.

These experiments suggested that the influence of the excess of hydroxyl ions was considerable. In previous papers on the theory of peptisation,[1] it was shown that in the peptisation of ferric hydroxide in presence of sugar or glycerol, the colloid is unstable at the isoelectric point of the solution. It was also stated that with a ferric hydroxide colloid, it was easy to get the three states in the charge reversal of a colloid, namely—positively charged colloid, coagulation and then a negatively charged colloid. This would naturally mean that in the negatively charged colloid, the stability is due to the adsorbed negative ions. It would therefore be difficult to explain the function of non-electrolytes which help in this peptisation. In order to study the mechanism of this charge reversal or peptisation into either a positively charged or negatively charged

[1] Sen: Kolloid zeit., *36*, 113 (1925); Jour. Phys. Chem. *29*, 1533 (1925).

sol, some direct experiments have been made. The object was to find out whether there is any definite range of H° or OH′ ion concentration within which the colloid is unstable. In this paper the experiments with three colloids, $Ce(OH)_3$, $Fe(OH)_3$ and $Cr(OH)_3$ are given. The choice of these substances was made because of the ease with which all of them can be obtained either as positively charged or negatively charged colloids. The method of experimentation was practically the same as given in a recent paper by Mehrotra and Sen.

TABLE II.

Peptisation of Cerous Hydroxide.

Cerium Chloride = 1 milli-equivalent.
Sucrose = 2 millimoles.
Total Volume = 10 c.c.

Amount of NaOH added milli-equivalents.	Results and Remarks.
0·814 ...	Solution clear. Reaction acid. Colloid positive.
0·888 ...	Solution clears in a minute or two.
0·962 ...	Immediate precipitation.
1·036 ...	Do.
1·110 ...	Do.
1·184 ...	Solution slightly turbid. Reaction alkaline.
1·258 ...	Solution clear. Reaction alkaline. Colloid negative.

TABLE III.

Peptisation of Chromium Hydroxide.

Chromium chloride = 1 milli-equivalent.

Glycerol = 2 millimoles.

Volume = 10 c.c.

NaOH added.	Results and Remarks.
0·6 ...	Solution clear. Colloid positive. Reaction acid.
0·8 ...	Solution turbid but clears after some time. Reaction acid
0·90 ...	Precipitate.
1·0 ...	Reaction neutral. Flocculent precipitate which settles down easily.
1·2 ...	Solution slightly turbid. Reaction alkaline.
1·4 ...	Solution clear. Reaction alkaline. Colloid negative.

TABLE IV.

Peptisation of Ferric Hydroxide.

Ferric chloride = 0·5 milli-equivalent.

Glycerol = 1 millimole.

Volume = 10 c. c.

NaOH added.	Results and Remarks.
0·333 ...	Solution clear. Reaction acid. Positively charged colloid.
0·37 ...	Solution slightly turbid but clears within a short time.
0·444 ...	Solution turbid. Does not clear and does not settle. Reaction acid.

NaOH added.	Results and Remarks.
0·50 ...	Flocculent precipitate which settles down rapidly. Reaction neutral.
0·555 ...	Solution turbid. Does not settle easily but particles can be distinguished. Reaction alkaline.
0·629 ...	Solution turbid at first, but clears within a minute or two. Reaction alkaline. Colloid negatively charged.
0·70 ...	Solution clear. Colloid negative.

Tables II, III and IV show definitely that when an exactly equivalent amount of alkali is added to solutions of cerium, iron or chromium chlorides, a precipitate is formed even in presence of a protective non-electrolyte. There is a definite range of acid or alkali concentration within which the colloid is unstable, but beyond this range, the colloid can be obtained either as positively charged or negatively charged particles. Thus the range within which cerium hydroxide is unstable is about 0·8 to 1·2 milli-equivalents of caustic soda. With ferric hydroxide and chromic hydroxide, the ranges are respectively 0·4 to 0·6 and 0·8 to 1·2 milli-equivalents of alkali. It is to be noted that these concentration ranges are only for the particular concentrations of the metal ions used. These results thus point to the following fact: In presence of non-electrolytes like sugar or glycerol, colloidal cerium, iron and chromium hydroxides can be obtained either as positively charged or negatively charged particles depending upon the concentration of the added alkali only when there is a minimum excess of either acid or alkali present in the solution. If a minimum excess be not present, then no peptisation can be obtained. In other words, non-electrolytes

like sugar and glycerol do not exert any protective effect upon cerium, iron and chromium hydroxides in the absence of excess of H° or OH′ ions or other easily adsorbable ions.

Mention may be made here of another interesting fact. According to Wo. Pauli,[1] many proteins exert no protective action on a gold sol which has been freed to the greatest possible extent from electrolytes. Freundlich[2] therefore concludes that a certain content of electrolyte is necessary for the protective action of many, perhaps of all, protective colloids. J. Loeb[3] also found that isoelectric gelatine does not protect a collodion sol in the absence of electrolytes, but when certain electrolytes are present, this protection is observed. It is very likely that in these cases, a preferential adsorption of some ions by the proteins makes them behave like charged colloids, and the protection is thus due to an electric film formation.[4] Consequently the general statement[5] that *the protective action of the so-called protective colloids and non-electrolytes is dependent on the presence of easily adsorbable ions in the solution*, seems to be true.

From a perusal of Tables II, III, and IV it will be observed that these experiments are nothing but titrations of the metallic chlorides by caustic soda in presence of non-electrolytes. The reactions are thus of a similar nature to that found by Lottermoser[6] in the case of silver nitrate and potash iodide, where an excess of either reagent would facilitate and was necessary for the formation of a colloid, but in exactly equivalent proportion, a precipitate would result, a fact which can be explained on the views of

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[1] Kolloid zeit. *31*, 252 (1922).

[2] Kapillarchenise. English Trans., p. 834 (1926).

[3] Jour. Gen. Physiol., *5*, 479—504 (1923).

[4] Sen: Kolloid zeit., *36*, 199 (1925).

[5] Sen: Ibid., p. 202

[6] Loc cit.

Powis[1] regarding the existence of a critical potential below which the colloid is unstable. Carrying this analogy further, we can say that the peptisation of metallic hydroxides is an ionic one like that of the silver halides and is brought about by the preferential adsorption of the constituent ions of the colloid, namely OH' or the metal ion or may be in some cases H° ions, and thus the rôle played by the non-electrolytes must be considered to be a secondary one. If this is so, then the question arises, how do the non-electrolytes help in the observed peptisation? It may be taken for granted that the non-electrolytes are more or less adsorbed by the metallic hydroxides. This adsorption will thus lower the surface tension of the adsorbent. Possibly the surface of the adsorbent will become more hydrated. Another effect of the adsorption will be the inhibition of the growth of the particles either by coalescence or crystallisation. Thus from the experiments of Marc and Wenk,[2] Pickardt[3] and Padoa and Galeati,[4] we know that the adsorption of a non-electrolyte greatly decreases the velocity of crystallisation. It is quite possible that a similar thing happens here. The peptisation of the hydroxide by the ions will thus be greatly facilitated. Another probable effect of the adsorption of the sugars, though it lacks as yet experimental confirmation, may be to increase the amount of hydroxyl ion adsorption. That the adsorption of some non-electrolytes can increase the amount of adsorption of an ion has already been shown in the case of hydrated manganese dioxide and copper and silver ions in presence of sucrose and alcohol.[5] Whatever may be the real

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[1] Zeit physik chem. *89*, 186 (1915).
[2] Zeit physik chem. *68*, 112 (1910).
[3] *Ibid.*, *42*, 27 (1902).
[4] Gazz, chim. ital. *35*, I, 181 (1904).
[5] Sen: Kolloid zeit., *38*, 310 (1926).
Also compare Abderhalden and Fodor.
Fermentforschung, *2*, 74 (1917); *2*, 151, 217 (1918).
Kolloid zeit, *27*, 49 (1920).

effect of these non-electrolytes, it is clear that they play a minor rôle than the OH' ions in the peptisation of metallic hydroxides investigated in this paper, and it is likely that the real peptising agent, at least in the cases of Ce, Fe and Cr hydroxides, is the OH' ion when alkali is present in excess, the non-electrolytes influencing the peptisation only indirectly.

SUMMARY.

1. A theoretical and experimental study has been made of the peptisation of certain metallic hydroxides. It has been shown that in the case of cerium, iron and chromium hydroxides in presence of non-electrolytes, a minimum excess of H° or OH' ions is necessary for peptisation.

2. The conclusion has therefore been drawn that non-electrolytes like sugars, glycerol, etc., cannot by themselves peptise any metallic hydroxides, but afford a protective effect only in presence of electrolytes.

3. A similar fact seems to be true in the case of proteins also, namely, their protective effect is only manifested in presence of electrolytes.

4. Consequently it is desirable to investigate whether the proteins act as protective colloids only when they exist in solution as charged colloids owing to the adsorption of ions, and not as amphoteric electrolyte-free substances.

5. It is probably possible to make a general statement about the nature of the protective effect afforded by the non-electrolytes:—The non-electrolytes help the ionic peptisation of the metallic hydroxides when they are present in the solution. Their rôle is however quite subordinate to that of the ions. Their effect is probably on the surface of the particles—diminishing the surface energy, increasing hydration and inhibiting the growth of the particles either by coalescence or crystallisation. The electro-kinetic behaviour shown by cerium, iron and chromium hydroxide colloids in presence of these non-electrolytes compels us to believe that their stability is undoubtedly more determined by the electric double layer existing between the particles and the solution than by anything else.

SECTION V

MATHEMATICS

A THEOREM CONCERNING ZEROS OF AN ANALYTIC FUNCTION

BY

P. L. SRIVASTAVA

My thanks are due to Prof. G. H. Hardy, under whose guidance the following theorem was obtained.

Theorem.—If

(*i*) $f\,(z)$ *is an analytic function of* $z=\rho e^{i\psi}$ *in the angle* $|\psi| \leqq \alpha$, *where* $0<\alpha<\frac{\pi}{2}$;

(*ii*) $$\limsup_{\rho \to \infty} \frac{\log |f(\rho e^{i\psi})|}{\rho} = \lambda(\psi),$$

where $\lambda(\psi)$ *is bounded for* $|\psi| \leqq \alpha$;

(*iii*) $\frac{\lambda(\alpha)+\lambda(-\alpha)}{2} - k\cos\alpha < \pi\sin\alpha$, *where* $k=\lambda(0)$;

then $f\,(z)$ *cannot have zeros at all the points* $z=0, 1, 2, 3, \ldots$

Suppose, if possible, that $f\,(z)$ has zeros at the specified points. Now consider the function

$$g\,(z) \equiv \frac{f(z)}{\sin \pi z} e^{-kz}.$$

Then[1]

$$g\,(z) = O\,(e^{L\rho}),$$

where L is a constant, uniformly in the angle $|\psi| \leqq \alpha$.

Let $h\,(\psi)$ be formed from $g(z)$ as $\lambda(\psi)$ is from $f\,(z)$.

[1] See 'Note by Mr. Hardy,' *Proc. Camb. Phil. Soc.*, Vol. XX, pp. 208-209.

Then it is obvious that

$$h\ (\pm\ \alpha) = \lambda(\pm\alpha) - k\ \cos\ \alpha - \pi\ \sin\ \alpha.$$

It follows, therefore, from the beautiful memoir of Phragmén and Lindelöf[1] that

$$h\ (0) \leqq \left(\frac{\lambda\ (\alpha) + \lambda\ (-\alpha)}{2} - k \cos\alpha - \pi\ \sin\alpha \right)$$

$$< 0, \qquad \text{by (iii)}\ .$$

But evidently $h\ (0) \geqq 0$. Thus we are involved in a contradiction. Hence $f(z)$ cannot have zeros at all the points $z=0, 1, 2, 3, \ldots$.

If $\alpha = \frac{\pi}{2}$, then the conclusion of the theorem holds under more general hypotheses.[2]

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[1] 'Sur une extension d'un principe classique de l'analyse et sur quelques propriètés des fonctions monogènes dans le voisinage d'un point singulier,' *Acta Mathematica*, Vol. 31, 1908, pp. 381—406. See the theorem of § 10.

[2] F. Carlson, '*Sur une classe de séries de Taylor*,' Thése pour le doctorat, Upsal, 1914, p. 58. Also see G. H. Hardy, 'On two theorems of F. Carlson and S. Wigert,' *Acta Mathematica*, Vol. 42, pp. 327—339. I take this opportunity to point out that Hardy's first proof of Carlson's theorem (with $\alpha = \frac{\pi}{2}$) is incomplete in so far as it omits to consider explicitly the case $h\ (\theta) = -\infty$ for $|\theta| < \frac{\pi}{2}$. That the hypotheses (1), (2), and $f(z)$ not identically zero are not sufficient to ensure the continuity of $h\ (\theta)$ for $|\theta| < \frac{\pi}{2}$ is shown by the function $\frac{1}{\Gamma(z+1)}$.

In this connection see also M. Riesz, 'Sur le principe de Phragmén-Lindelöf,' *Proc. Camb. Phil. Soc.*, Vol. XX, pp. 205—207.

ARTS

SECTION I

ENGLISH

A NOTE ON WORDSWORTH'S METAPHYSICAL SYSTEM.

BY

S. G. DUNN, M.A., I.E.S.

It is salutary for one who would endeavour, as I shall endeavour in this note, to " extract the system " from the poems of Wordsworth, to bear in mind that " the poet writes under one restriction only, namely, the necessity of giving immediate pleasure to a human Being possessed of that information which may be expected from him, not as a lawyer, a physician, a mariner, an astronomer, or a natural philosopher, but as a Man."[1] The primary value of Wordsworth's poetry is, indeed, the revelation of Joy " in widest commonalty spread ";—it does enable us to find, for this uneasy heart of ours,

> " A never-failing principle of Joy
> And purest passion."

Yet, Wordsworth himself, in dividing into classes the readers of poetry, tells us, " There are many, who having been enamoured of this art in their youth, have found leisure, after youth was spent, to cultivate general literature; in which poetry has continued to be comprehended *as a study*."[2] It may be conceded, then, to a Professor whose function (not alas! exercised in leisure) it is " to cultivate general literature, that he should make a *study* of poetry, especially when he is invited thereto by the poet. For in the Preface to the *Excursion* (1814) Wordsworth, while renouncing the intention " formally to announce a system," hopes that " if he shall succeed in conveying to the mind clear thoughts, lively images and strong feelings, the Reader will have no difficulty in extracting the system for himself." Let us start with this Preface, for it tells us how to proceed in our search for a system.

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[1] Preface to Second Edition of Lyrical Ballads (1800).

[2] Essay Supplementary to Preface (1815).

As early as 1795, Wordsworth had set before him the accomplishment of a great philosophical poem, "*On Man, On Nature,* and *On Human Life.*" In March, 1798, he states, in letters, that he has written "1,300 lines of a poem in which I contrive to convey most of the knowledge of which I am possessed. My object is to give pictures of Nature, Man and Society. . . . Its title will be the *Recluse; or Views of Nature, Man, and Society.*" Some of these lines are embodied in the later *Prelude*, others appear in the Preface to the *Excursion* "as a kind of *Prospectus* of the design and scope of the whole Poem." The following passage outlines his scheme; his intention is to proclaim,

> "How exquisitely the individual Mind
> (And the progressive powers perhaps no less
> Of the whole species) to the external World
> Is fitted:—and how exquisitely, too—
> Theme this but little heard of among men—
> The external World is fitted to the Mind;
> And the creation (by no lower name
> Can it be called) which they with blended might
> Accomplish:—this is our high argument."

In other words, he is to attempt nothing less than a solution of the problem which had puzzled the eighteenth century. Briefly put, that problem is this. On the one side, we have Man in his duality of Mind and body; on the other, Nature or the external world; Mind *versus* Matter. What is the link, if there is a link, between them? How does Man get his knowledge, if knowledge it can be called, of the external world? For if there is no link, there can be no knowledge; either Mind is Matter, if we follow Locke to his logical conclusions, or Matter is Mind, if we follow Berkeley to his conclusions. Crudely summarized, that is the problem. To avoid this awkward dilemma, the natural man, that is, the man who interrogates his own feelings and intuitions, his own body and mind,—and the

poet is the natural man raised to the highest power,—Wordsworth, let us say, combines the two, and boldly asserts that reality, the world as we know it, is the creation of both Mind and Matter; we half perceive and half create; there is a "mutual domination" and "interchangeable supremacy" between Mind and Matter. That is the position reached by common sense, but it remains to justify it philosophically, and this is what Wordsworth set out to do in the *Recluse*. It was indeed a high argument, an epic theme needing the power of a Dante or a Milton. Had he that power? At first, apparently, he had no misgivings. In the glad confident morning of his genius, during those days in the West country with Coleridge and with his sister, he began the task. But if the talk of Coleridge could inspire, it could also bewilder with doubtful speculations. About the end of 1798, Wordsworth began to "take a review of his own mind, and examine how far Nature and Education had qualified him for such employment. As subsidiary to this preparation, he undertook to record, in verse, the origin and progress of his own powers, as far as he was acquainted with them."

This preliminary and autobiographical poem was completed in the winter of 1806-7 when it was read to Coleridge; but the manuscript, frequently revised, remained unpublished till the poet's death when it appeared in 1850 under the title of the *Prelude*. Of this more anon. After finishing this first part of the great poem, Wordsworth went on to the second stage, in which, instead of "meditation in the Author's own person," he employs "the intervention of characters speaking and something of a dramatic form." This, the *Excursion*, he published in 1814. In the Preface he speaks of it as the intermediate part of his poem the *Recluse;* the first part he has not completed "in such a manner as to satisfy his own mind," and the third part is not yet in being; he publishes this instalment because

"it does not depend upon the preceding to a degree which will materially injure its own peculiar interest." At the same time he advises the reader that it must be taken in relation with that first part (the *Prelude*), and with his other poems; he compares the whole body of his work to a "gothic church"; the *Prelude* is the ante-chapel, the *Excursion* the body of the church, the minor poems, as he calls them, the "little cells, oratories and sepulchral recesses, ordinarily included in those edifices."

This comparison is significant of the change which was happening in Wordsworth. The "genial sense of youth" had left him, and Joy was no longer "its own security"; he was beginning to lose his confidence in the "sovereignty within" of "natural beings in the strength of nature"; the Wordsworth who had joyously proclaimed, "Let nature be your teacher," was turning into the Wordsworth who wrote the *Ecclesiastical Sonnets*. Partly, it was a loss of "the visionary power" which he laments in the *Immortality Ode;* partly, it was a deliberate turning away from the natural religion of his youth towards the orthodox "piety" of his later years. Every student of Wordsworth has noted the change. It began about 1806. Prof. de Selincourt dates its beginning from the loss of his brother John in 1805. "There is every evidence," he says, "in the letters and elsewhere that Wordsworth was passionately devoted to his brother, and the shock of his loss seems to have made a turning point in the poet's thought. The beginning of the change from the naturalism and sensationalism of his early poetry to a more definitely orthodox attitude dates from this time."[1] Prof. Garrod traces it to the estrangement from Coleridge.[2] "From about 1806 Coleridge in fact ceased to be a direct

[1] The *Prelude*, edited by Ernest de Selincourt (Oxford, 1926).
[2] Wordsworth—Lectures and Essays by H. W. Garrod (Oxford, 1923).

formative influence in Wordsworth's life and thought." He refers appositely to the *Complaint* written in 1806: "There is a change and I am poor." The words, he says, are truer than Wordsworth meant them to be, or at any rate, far wider in their application. "He is speaking of the affections. But he is poorer, not only in the wealth of the affections, but in the riches of philosophic thought."

The real Wordsworth, the distinctive poet, is the Wordsworth of 1798 to 1807; it is to the work done in those years that we must go to find what he felt and what he thought at his best, his real system. It is true that he professes in the *Excursion* preface to regard that work as preparatory to the philosophical poem; even in the *Excursion* itself he is not prepared "formally to announce a system"; he contemplates a further instalment of his "sensations and opinions"; in that, no doubt, he would explain these, correlate them, and erect a theory such as he had adumbrated in the lines quoted from the *Prospectus*. But the years went on; the "long and laborious Work" stood still; he does not seem even to have started the third part of it; instead, he went back to the first and so altered it from time to time that, when at last it was published, the "sensations and opinions" expressed were in many passages different from those actually held and expressed in 1806. Fortunately, we are now able to read what was written in the early version and compare that with the version of 1850; for the first time we have before us that autobiographical poem which was read to Coleridge. The publication of Professor de Selincourt's edition of the *Prelude* in 1926 was made possible "through the kindness and generosity of the poet's grandson Mr. Gordon Wordsworth, the owner of the manuscripts on which it is based."[1] These manuscripts are described

[1] Preface to de Selincourt's edition of the *Prelude*.

by Professor de Selincourt; there are " five almost complete extant manuscripts of the *Prelude* covering the years 1805—39 as well as several notebooks and other manuscripts, which contain drafts of parts of the poem, and belong to an earlier period." In the new edition published by the Clarendon Press we have the text of 1850 side by side with the text of the poem as it was read to Coleridge, together with unpublished fragments which are often of the utmost importance. In quoting from the *Prelude* I shall refer to the early version as A and to the 1850 version as B.

We have, then, as our material from which to extract a system, the " minor " or lyrical poems, the *Prelude* A, and the *Excursion*, and in using these three we can trace the changes in thought by reference to *Prelude* B, since the differences between *Prelude* A and *Prelude* B will help us to understand how the Wordsworth of 1814 came to differ, as the *Excursion* shows us he did differ, from the Wordsworth of 1806.

But before proceeding further it is necessary to revert for a moment to the preface to the *Excursion*, and examine rather more closely Wordsworth's words. A study of the manuscripts newly available confirms the view that Wordsworth was extraordinarily careful about his words; every one of them has its weight; we shall miss his meaning if we pass over a word without realizing the significance it had for him. This is evident from the changes he made in his manuscript. For example, in the *Prelude* A, II. 258 the inmate of this active Universe

> " Even *as* an agent of the one great mind
> Creates, creator, and receiver both."

It is clear from his expressions elsewhere at this period that he believed Man to *be* the agent of the one great mind. Later he was afraid of this; it looked too much like Pantheism and he changed " Even as " to "Doth like "

and "mind" to "Mind." A less careful writer might argue that "Even as" can be interpreted as the equivalent of "like"; but Wordsworth made the change. He had all the conscientious exactitude of the great artist. For this reason it is worth while at the risk of repetition to look again at the wording of the *Preface*. There he tells us that he is not announcing a system, but trying to convey to the mind "clear thoughts, lively images and strong feelings," because that course is "more animating" to him. The two essential phrases are, it seems to me, "animating"—a favourite word of Wordsworth's —and "conveying to the mind." If one remembers his habitual process of composition and the theory upon which he worked, these phrases are illuminating.

Poetry, according to Wordsworth, "is the spontaneous overflow of powerful feelings: it takes its origin from emotion recollected in tranquillity: the emotion is contemplated till, by a species of reaction, the tranquillity gradually disappears, and an emotion, kindred to that which was before the subject of contemplation, is gradually produced and does itself actually exist in the mind. In this mood successful composition generally begins, and in a mood similar to this it is carried on."[1] In other words, an object, an event, let us say, of any kind, be it physical as the sight of the rainbow in the sky, or spiritual, as the contemplation of the lonely leech-gatherer, produces a powerful emotion; the inward eye—a special faculty, distinct, apparently, from memory,—is able to convey this object to the mind after the first powerful feeling has subsided; the mind, by the contemplation of this object presented to it by the inward eye, is roused, or "animated," to an emotion kindred to that originally excited, but purged of the merely transient and associated with the permanent and universal; in this mood the

[1] Preface, 1800.

creative faculty, or imagination, works, and the poem is produced. Elsewhere, Wordsworth lays stress on the necessity of this interval for contemplation; he is, *e.g.*,

> " not used to make
> A present joy the matter of a song,"
>
> (*Prelude*, I. 46)

and if we remember this, we shall realise the importance to him of the " inward eye " which can recall what the " visionary power " has once enabled him to see. His theory had been anticipated by Akenside who expresses in the following lines precisely the same idea :

> "Let me once more feel
> Your influence, O ye kind inspiring powers;
> And I will guard it well; nor shall a thought
> Rise in my mind, nor shall a passion move
> Across my bosom unobserved, unstored
> By faithful memory. And then at some
> More active moment, will I call them forth
> Anew; and join them in majestic forms
> And give them utterance in harmonious strains;
> That all mankind shall wonder at your sway."
>
> (*Inscription*, VIII).

The " active moment " here is exactly that mood of " animation " which Wordsworth expects to follow "by a species of reaction " on the contemplation of the emotion made possible by the " faithful memory " or, as he prefers, " the inward eye."

It should now be clear what he means by " animating " and " conveying to the mind." His purpose in all this poetry preliminary to the great philosophical poem—the *Prelude*, the *Excursion* and the other poems —is to preserve " clear thoughts, lively images and strong feelings " as the records upon which the imagination may work when it comes to organize or animate his feelings or intuitions, to give an intellectual life, a system, to his perceptions of truth, to bring the intimations of

the heart into relation with the philosophic mind. This purpose becomes clearer still in a passage of the *Prelude.*

> " I see by glimpses now; when age comes on,
> May scarcely see at all, and I would give,
> While yet we may, as far as words can give,
> A substance and a life to what I feel:
> I would enshrine the spirit of the past
> For future restoration."
>
> (*Prelude* A, XI. 281).

It is a pathetic passage indicating, as it does, that even when he wrote it, before 1807, he felt the " visionary power " was passing from him; it becomes yet more pathetic in the later version which reads,

> " enshrining,
> Such is my hope, the spirit of the Past
> For future restoration."—
>
> (*Prelude* B, XII. 284).

That " restoration," in the sense he used the word, was not to be; what he intended by it and what he meant by " animation," is evident from the *Prelude* A, II. 245 (a passage which contains a significant alteration, to which reference has already been made, in the later version)

> " Emphatically such a being lives,
> An inmate of this *active* universe;
> From nature largely he receives; nor so
> Is satisfied, but largely gives again,
> For feeling has to him imparted strength,
> And powerful in all sentiments of grief,
> Of exultation, fear, and joy, his mind,
> Even as an agent of the one great mind,
> Creates, creator and receiver both,
> Working but in alliance with the works
> Which it beholds."—

The " restoration " of which he speaks is the awakening of the " poetic spirit," that " shaping spirit of imagination," the loss of which Coleridge deplored in himself, and which Wordsworth no less was losing when he wrote those lines.

Enough has now been said to show that if we would "extract a system" we must examine the records of his experience which Wordsworth has enshrined for future restoration. Having done this, we may go on to ask what kind of explanation Wordsworth himself has to offer, bearing in mind, however, that the explanation was never worked out by him formally as he had intended to work it out in the final book of the *Recluse;* all we have is a tentative approach to an explanation in some passages of the *Prelude* and the *Excursion.*

The salient fact of Wordsworth's experience is evidently his conviction of a life in things, a life which is akin to the life in man, but deeper, wider and more intense. It is by contact with this life in things, or with Nature, that man grows in moral strength and wisdom and realises his true immortal being. At first this contact is through the senses; it is by the eye and the ear that man becomes aware of this life of Nature, and through the eye and ear—the language of the sense—that he can listen to the voice of Nature and learn from it. In the *Lines composed a few miles above Tintern Abbey*, Wordsworth is

> "well pleased to recognise
> In nature and the language of the sense,
> The anchor of my purest thoughts, the nurse,
> The guide, the guardian of my heart, and soul
> Of all my moral being."

Therefore, he tells us, he is

> "A lover of the meadows and the woods,
> And mountains; and of all that we behold
> From this green earth; of all the mighty world
> Of eye, and ear,—both what they half create,
> And what perceive;"

This latter passage introduces a new element; man is not merely recipient, but creative; he stands in Nature's presence

> "A sensitive, and a creative soul."

(*Prelude* A, XI. 206).

It is not quite true, it seems to me, to assert as Professor Garrod, for example, asserts, that Wordsworth is " a pure sensationalist," regarding the senses as the source of truth. The lines in *Tintern Abbey* with their emphasis on the eye and ear should be read with passages such as that quoted above (Prelude A, II. 245) and many others where it is unmistakably assumed that reality is the result of an interaction, or

> " interchange
> Of action from within and from without,
> The excellence, pure spirit, and best power
> Both of the object seen, and eye that sees."
>
> (*Prelude* A, XII. 378)

Here the " eye " means, I suggest, more than the sense; it implies the " creative soul " behind the eye. To understand this the account of the ascent of Snowdon and the meditation that follows in the last book of the *Prelude* should be read. The higher minds are

> " By sensible impressions not enthrall'd;"

They

> " build up greatest things
> From least suggestions, ever on the watch,
> Willing to work and to be wrought upon."

That the " soul " as well as the " eye " is concerned in this intercourse with the " great world of eye and ear " is evident from the *Excursion* (IV. 109) where he recalls

> " What visionary powers of eye and soul
> In youth were mine."

The manuscript Y, newly available, also throws light on this matter. There Wordsworth sketches, somewhat in the same manner as in *Tintern Abbey*, the growth of the true feeling for Nature, characteristic of the higher being, as distinguished from the mere animal delight of " untutor'd minds." In early days,

> " everyday appearances, which now
> The spirit of thoughtful wonder first pervades,
> Crowd in and give the mind its needful food."

Later, " contrasts strong and harsh " are needed to make the " Spirits dance "; vivid images and strong sensations must be given to rouse the " untutor'd mind " to recognition of a life beyond its own; else, the man is

> " his own person, senses, faculties,
> Centre and soul of all."

It is this attitude that Wordsworth scorns in *The Poet's Epitaph*, the attitude of the man who relies on the " meddling intellect "; this mis-shapes the beauteous forms of things because it makes itself the measure of all things and does not perceive the life in them,

> " Viewing all objects unremittingly
> In disconnection dead and spiritless."

Hence his quarrel in the same book of the *Excursion* (IV. 987) with

> " Philosophers, who, though the human soul
> Be of a thousand faculties composed,
> And twice ten thousand interests, do yet prize
> This soul, and the transcendent universe,
> No more than as a mirror that reflects
> To proud self-love her own intelligence;
> That one, poor, finite object, in the abyss
> Of infinite Being, twinkling restlessly."

It is important to get Wordsworth's distinction between this *Intellect* or secondary power, and the *Reason* or the mind's *excursive* power, quite clear, in order to understand how the soul and eye co-operate so that we half-create and half-perceive. Of this secondary power he speaks to Coleridge in the second book of the *Prelude* B (II. 215)

> " No officious slave
> Art thou of that false secondary power
> By which we multiply distinctions, then
> Deem that our puny boundaries are things
> That we perceive, and not that we have made.
> To thee, unblinded by these formal arts,
> The unity of all hath been revealed."

Science, in his belief, will be worthy of her name, when

> "her dull eye,
> Dull and inanimate, no more shall hang
> Chained to its object in brute slavery;
> But taught with patient interest to watch
> The processes of things, and serve the cause
> Of order and distinctness, not for this
> Shall it forget that its most noble use,
> Its most illustrious province, must be found
> In furnishing clear guidance, a support
> Not treacherous, to the mind's *excursive* power.
> —So build we up the Being that we are;
> Thus deeply drinking in the soul of things,
> We shall be wise perforce."
>
> (*Excursion*, IV. 1254).

The "wise passiveness" in which we can "feed this mind of ours" is the passiveness of this secondary power of the mind; that other power, the excursive is wide awake, and by it we drink in the soul of things. The senses indeed are the medium of communication, but it is this power of the mind that uses their report, and it is by this power that

> "sense is made
> Subservient still to moral purposes,
> Auxiliar to divine,"

Hence it comes that

> "One impulse from a vernal wood
> May teach you more of man,
> Of moral evil and of good,
> Than all the sages can."

It does not seem to me, then, quite adequate to describe Wordsworth as a sensationalist: truth for him is derived from visionary powers, certainly, but visionary powers of eye *and* soul.

To revert to MS. Y, and the second stage, to which the "untutor'd mind" of scientists and philosophers does not attain.

> "Then will come
> Another soul, spring, centre of his being,
> And that is Nature. As his powers advance,
> He is not like a man who sees in the heavens
> A blue vault merely and a glittering cloud,
> One old familiar pageant, known too well
> To be regarded."

He takes the "optic tube of thought," and

> "Without the glass of Galileo sees
> What Galileo saw; and as it were
> Resolving into one great faculty
> Of being bodily eye and spiritual need,
> The converse which he holds is limitless;
> Not only with the firmament of thought,
> But nearer home he looks with the same eye
> Through the entire abyss of things."

In this season of his second birth,

> "He feels that, be his mind however great
> In aspiration, the universe in which
> He lives is equal to his mind;"

all that he feels of dignity in himself,

> "Sublimities, grave beauty, excellence,"

from which he gathers hope,

> "There doth he feel its counterpart the same
> In kind before him outwardly express'd,
> With difference that makes the likeness clear."

We see now how Nature can teach more than all the sages can, more effectively than art or history, for

> "'tis not here
> Record of what hath been, is now no more,
> No secondary work of mimic skill,
> Transcripts that do but mock their archetypes;
> But primary and independent life."

This explains the exhortation

> "Come forth into the light of things,
> Let Nature be your Teacher."

This conviction of "a primary and independent life," in

all about him was Wordsworth's earliest and most abiding impression. We have the record of it in many places. There is that evening on Ullswater when

> "a huge peak, black and huge,
> As if with voluntary power instinct
> Upreared its head"

and

> "like a living thing,
> Strode after me."

Thereafter, for weeks,

> "huge and mighty forms that do not live
> Like living men, moved slowly through the mind
> By day, and were a trouble to my dreams"
> (*Prelude*, I. 400).

He dramatizes this experience in the *Excursion* where the *Wanderer*

> "In solitude returning, saw the hills
> Grow larger in the darkness,"

and

> "While yet a child, and long before his time,
> Had he perceived the presence and the power
> Of greatness;"

At Cambridge,

> "To every natural form, rock, fruit or flower,
> Even the loose stones that cover the high-way,
> I gave a moral life, I saw them feel,
> Or link'd them to some feeling: the great mass
> Lay bedded in a quickening soul and all
> That I beheld respired with inward meaning.
> Thus much for the one Presence, and the Life
> Of the great whole."
> (*Prelude* A, III. 130).

Walt Whitman records a similar feeling, and perhaps he was thinking of this passage when he wrote,

> "You paths worn in the irregular hollows by the road-side!
> I believe you are latent with unseen existences,
> you are so dear to me."

One other instance must suffice, the well-known Blea Tarn episode in the *Excursion* (II. 691), which must have been in the mind of Shelley when he wrote the similar lines in his "Mont Blanc."[1] The two peaks that peer into the Solitary's vale and are his prized companions, seem to be the attraction of mute agents as busy about them as thoughts in the mind of man. They yield together a harmony though there be no voice;

> "the clouds,
> The mist, the shadows, light of golden suns,
> Motions of moonlight, all come thither—touch,
> And have an answer—thither come, and shape
> A language not unwelcome to sick hearts."

Hitherto we have been considering passages that record the perception of a life in things or outward objects. How does this perception affect the mind, feed it? How can Nature be said to "teach," to be the "nurse, the guide, the guardian" of the heart and moral being?

In the minor poems—those adjuncts of the main edifice in which the "system" is enshrined—Wordsworth appears mainly to draw "lessons" from, or moralize, Nature and natural objects in the manner of eighteenth and seventeenth century poets. He deduces his "great task of happiness" from listening to "the thousand blended notes" of early spring:

> "To her fair works did Nature link
> The human soul that through me ran;
> And much it grieved my heart to think
> What man has made of man."

He is compelled to think that there is pleasure all round him, in the birds, in the primroses; the voice of Nature bids him rejoice and he repeats the bidding to his fellow men,—take your temper from to-day and tune the measure of your souls to love. The daisy, the lesser celandine, the

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[1] *Excursion* published 1814; *Mont Blanc* composed 1816.

primrose on the rock have each their message of cheerful resignation, fortitude, peaceful acceptance; the lark soaring above its nest tells his heart to be true to the kindred points of heaven and home; the shouting cuckoo and the mountain echo waken the thought of

> "Echoes from beyond the grave;
> Recognised intelligence."

In all these poems Nature may be said rather to stimulate the fancy or imagination than directly to inspire or influence the soul. In the Lucy group of poems the direct influence of Nature is more apparent. Here Wordsworth is in the line of Plato; beauty and grace in human life may grow by silent sympathy with the forms and motions of the visible world; nature is both law and impulse,

> "an overseeing power
> To kindle or restrain."

In the *Excursion* we are shown in several passages how strength and peace of mind may be gained, or restored, by living

> "Not with the mean and vulgar works of Man,
> But with high objects, with enduring things,
> With life and nature, purifying thus
> The elements of feeling and of thought,
> And sanctifying, by such discipline,
> Both pain and fear, until we recognise
> A grandeur in the beatings of the heart."
>
> (*Prelude* A, I. 408)

The Wanderer is intended to represent a man who lives habitually in this spirit; he roams the countryside

> "Where living things, and things inanimate,
> Do speak, at Heaven's command, to eye and ear,
> And speak to social reason's inner sense,
> With inarticulate language."
>
> (*Excursion*, IV. 1205)

(Note, by the way, here, the words " at Heaven's command "; they are indicative of the change in Wordsworth

at this date from his early natural piety to more conventional theology.) The effect of this habitual reference to universal or natural standards as more authentic than the narrower human instincts is evident in the Wanderer's reaction to the sorrowful story of Margaret outside whose desolate cottage that story is told. At the most affecting point he breaks off and interposes,

> " 'Tis now the hour of deepest noon.
> At this still season of repose and peace,
> This hour when all things which are not at rest
> Are cheerful; while this multitude of flies
> With tuneful hum is filling all the air;
> Why should a tear be on an old Man's cheek?
> Why should we thus, with an untoward mind,
> And in the weakness of humanity,
> From natural wisdom turn our hearts away;
> To natural comfort shut our eyes and ears;
> And, feeding on disquiet, thus disturb
> The calm of nature with our restless thoughts?"
>
> (*Excursion*, I. 591).

And when the tale of suffering is over,

> " Why then should we read
> The forms of things with an unworthy eye?
> She sleeps in the calm earth, and peace is here."

It is this peace,

> " The central feeling of all happiness,
> Not as a refuge from distress or pain,
> A breathing-time, vacation, or a truce,
> But for its absolute self; a life of peace,
> Stability without regret or fear;"

which Wordsworth seeks and believes may be found by listening to the inarticulate language of Nature.

It may be objected and has been objected, against him that Wordsworth " averts his ken " from all those facts of the struggle for existence which would disturb his belief in Nature's holy plan. He was essentially of the eighteenth century in his cosmological optimism, though

he broke away from its political quietism and could condemn with the loudest of the Romantic reformers "the panic dread of change" and the "timid selfishness" of those who regarded society as organised in the best of possible ways. Not yet had biological research revealed the cruelties of evolution and the remorseless indifference of Nature "red in tooth and claw." Not yet could it be said "Of the Kosmos in the last resort, science reports many doubtful things, and all of them appalling."

For Wordsworth still at the end of that century as for Addison at its beginning

> "The Spacious Firmament on high,
> With all the blue Ethereal Sky,
> And spangled Heav'ns, a Shining Frame,
> Their great Original proclaim."
>
> (*Addison*)

Yet Wordsworth would have had an answer to the objectors and I am not sure that he has not already given one already by anticipation. The question of origins, so distressing to the inhabitants of Dayton, Tennessee, would certainly not have given him a moment's despondency. In the person of the Solitary (*Excursion*, III. 233) we can hear him say,

> "I, without reluctance, could decline
> All act of inquisition whence we rise,
> And what, when breath hath ceased, we may become.
> Here are we, in a bright and breathing world.
> Our origin, what matters it?"

To those who exclaim, "Ah! but there's the rub! It is *not* a bright world!" he would retort, again with the words of the Solitary,

> "I did not rank with those (too dull or nice,
> For to my judgment such they then appeared,
> Or too aspiring, thankless at the best)
> Who, in this frame of human life, perceive
> An object whereunto their souls are tied

In discontented wedlock; nor did e'er,
From me, those dark impervious shades, that hang
Upon the region whither we are bound,
Exclude a power to enjoy the vital beams
Of present sunshine."

In the face of all the cruel elements in Nature, cruel, that is, as they appear to man with his limited outlook, to the fury of the autumn winds and the bursting clouds, he affirms,

"Your desolating sway
Sheds, I exclaimed, no sadness upon me,
And no disorder in your rage I find,
What dignity, what beauty, in this change
From mild to angry, and from sad to gay,
Alternate and revolving! How benign,
How rich in animation and delight,
How bountiful these elements—compared
With aught, as more desirable and fair,
Devised by fancy for the golden age."

Yes! that is the Wordsworthian answer. If this world is not always bright, it is breathing; if not kindly, it is always animated. Accept it, as the animals accept it:

"With Nature never do *they* wage
A foolish strife; they see
A happy youth, and their old age
Is beautiful and free."

Again he anticipates Walt Whitman, just as he anticipates Browning in "the value and significance of flesh," and Meredith in the acceptance of Nature,

"Granite the thought to stay
That she is a thing alive
To the living, the falling and strewn."

It is to that life of Nature we come ultimately in our search for the central point of Wordsworth's philosophy. We have seen how Man has contact with that life through the co-operation of the senses with his soul or excursive mind, and how that contact moulds his feelings and

strengthens his whole moral being. But so far that life has been regarded, even thus, as a life external to his own, linked in some mysterious way to the human soul, but not, in the strict sense, his own. In the passages which follow we advance to reality as Wordsworth conceives it, the transcendence of the senses, the time of ecstasy and union, when

"Communing with the glorious universe"

man becomes a living soul; his finite existence is one with the infinite, is "possessed" by it, or "swallowed up" in it. In this serene and blessed mood,

"the breath of this corporeal frame
And even the motion of our human blood
Almost suspended, we are laid asleep
In body, and become a living soul:
While with an eye made quiet by the power
Of harmony, and the deep power of joy,
We see into the life of things"

(*Tintern Abbey*).

This passage written in 1798 may be compared with that in the *Excursion* where he transfers to the Wanderer in youth his own experience at sunrise on a headland over the sea.

"Far and wide the clouds were touched,
And in their silent faces could be read
Unutterable love. Sound needed none,
Nor any voice of joy; his spirit drank
The spectacle; sensation, soul, and form,
All melted into him; they swallowed up
His animal being; in them did he live,
And by them did he live; they were his life.
In such access of mind, in such high hour
Of visitation from the living God,
Thought was not; in enjoyment it expired."

(*Excursion*, I. 203).

Elsewhere (*Excursion*, IV. 1140) he compares the Universe to a shell murmuring mysterious union with its native sea;

"and there are times,
I doubt not, when to you it doth impart
Authentic tidings of invisible things;
Of ebb and flow, and ever-during power;
And central peace, subsisting at the heart
Of endless agitation."

Here already the change is perceptible; we have "authentic tidings" instead of seeing into the life of things; it is "to the ear of Faith" that the universe is a shell. The contrast between the earlier and the later Wordsworth, between what he actually felt at his best and what afterwards he attempted by way of explanation of his feeling, may be seen by comparing two passages from earlier and later work. First, this characteristic declaration from *Prelude* A, V. 12,

"Hitherto,
In progress through this Verse, my mind hath look'd
Upon the speaking face of earth and heaven
As her prime Teacher, intercourse with man
Establish'd by the sovereign Intellect,
Who through that bodily Image hath diffus'd
A soul divine which we participate,
A deathless spirit."

The "spiritual sovereignty" of man, the "dignity" of his being, his "majestic" intellect and "unconquerable" mind are frequently acclaimed in the years when these lines were composed, *i.e.*, before 1807. In *Prelude* A, III. 193, he asserts

"there's not a man
That lives who hath not had his godlike hours,
And knows not what majestic sway we have,
As natural beings in the strength of nature."

Note that well; we have majestic sway as *natural* beings in the *strength* of *nature*.

Now turn for the contrast to No. XX of the Ecclesiastical Sonnets, published in 1827, on *Baptism*:

"Dear be the Church that, watching o'er the needs
Of infancy, provides a timely shower
Whose virtue changes to a Christian Flower
A Growth from sinful Nature's bed of weeds!"—

Gone is the majestic sway we have as natural beings in the strength of nature; what has become of the Heaven that "lies about us in our infancy"? Here is indeed "a heavy change" in Wordsworth, and as he changed, so he altered what he had written. The passage quoted above, characteristic as I have described it of his whole attitude at the time when it was composed, appears in the later version without the line

"A soul divine which we participate,"

and, instead, we read

"As might appear to the eye of fleeting time,
A deathless spirit."

His confident conviction of participation in the divine soul of nature, nay, his perception of the divinity of that soul of nature itself, is now relegated to the limbo of illusion. Nature,

"The guide, the guardian of my heart, and soul
Of all my moral being,"

is now seen as sinful, a bed of weeds! What is the cause of this remarkable change? Why does the Wordsworth of 1814 or 1827 repudiate the Wordsworth of 1798-1807? The time factor is important. Up to the completion of *Prelude* A, *i.e.*, up to 1807 Wordsworth was recording his experience, putting down as exactly as he could what he had felt, seen, known, himself. And in this record he is unique for sincerity and honesty. His record rings true. It is not always clear, because he is trying to express at times that which cannot be expressed in words; in speaking of the deepest experience we can but appeal to the consciousness of another; we cannot narrate, we can only suggest, "Is not this something like your own ex-

perience?" Wordsworth is aware of this impossibility of full and clear communication.

> " Of Genius, Power,
> Creation and Divinity itself
> I have been speaking, for my theme has been
> What pass'd within me. . . . .
> but in the main
> It lies far hidden from the reach of words.
> Points have we all of us within our souls,
> Where all stand single; this I feel, and make
> Breathings for incommunicable powers.
> Yet each man is a memory to himself,
> And, therefore, now that I must quit this theme,
> I am not heartless; for there's not a man
> That lives who hath not had his godlike hours,
> And knows not what majestic sway we have,
> As natural beings in the strength of nature."
>
> (*Prelude* A, III. 173).

Opening our memories, recalling our experience, we acknowledge the truth of his record. He has expressed what all of us in our "godlike hours," either in the presence of nature or in meditation withdrawn from all outward things, have felt of immediate union with a life greater than, yet including, our own, when the soul seems to emerge and takes possession of or swallows up the ordinary working self, and we are . . . what? One with nature, one with God? Or merely visited by God, or aware of God?

> " It lies far hidden from the reach of words."

How does Wordsworth try to describe this experience? Some of his attempts we have quoted. Here are some more.

> " I have felt
> A presence that disturbs me with the joy
> Of elevated thoughts; a sense sublime
> Of something far more deeply interfused,
> Whose dwelling is the light of setting suns,
> And the round ocean and the living air,

And the blue sky, and in the mind of man:
A motion and a spirit, that impels
All thinking things, all objects of all thought,
And rolls through all things."

(*Tintern Abbey*).

Often quoted as these lines are they must be quoted again, because they contain the record which Wordsworth ultimately chose, as it seems to me, as the basis for the metaphysical explanation of his experience, and we shall have to return to them. But the passages in *Prelude* A are no less significant; only now can we read them in their original form; in the later versions they are modified in accordance with the change in Wordsworth's attitude.

(*a*) "I was only then
Contented when with bliss ineffable
I felt the sentiment of Being spread
O'er all that moves, and all that seemeth still,
. . . . for in all things now
I saw one life, and felt that it was joy."

(*Prelude* A, II. 400).

In the later version this becomes

"great the joy I felt,
Communing in this sort through earth and heaven
With every form of creature, as it looked
Towards the Uncreated with a countenance
Of adoration, with an eye of love."

(*b*) "I look'd for universal things; perused
The common countenance of earth and heaven;
And, turning the mind in upon itself,
Pored, watch'd, expected, listen'd; spread my thoughts
And spread them with a wider creeping; felt
Incumbencies more awful, visitings
Of the Upholder of the tranquil Soul,
Which underneath all passion lives secure
A steadfast life"

(*Prelude* A, III. 110).

This seems to describe what I have called above the emergence of the soul; but in the later version Wordsworth

separates the Upholder from the Soul by continuing from "soul" thus,

> "That tolerates the indignities of Time,
> And from the centre of Eternity
> All finite motions overruling, lives
> In glory immutable."
>
> (*Prelude* B, III. 121).

This places God, the Upholder, outside the soul instead of "underneath all passion," and conforms with the conventional idea of God in his Heaven (the centre of Eternity), controlling the world as the moon sways the tides.

(*c*) At Cambridge,

> "Hush'd, meanwhile,
> Was the under soul, lock'd up in such a calm,
> That not a leaf of the great nature stirr'd"
>
> (*Prelude* A, III. 540).

These lines do not appear at all in the later version.

(*d*) In speaking of the pleasure he derived from the "elements of geometric science" at Cambridge and his attempts to find "an alliance of those simple, pure proportions and relations with the frame and Laws of Nature," he goes on:

> "Yet from this source more frequently I drew
> A pleasure calm and deeper, a still sense
> Of permanent and universal sway
> And paramount endowment in the mind,
> An image not unworthy of the one
> Surpassing Life, which out of space and time,
> Nor touched by welterings of passion, is
> And hath the name of God. Transcendent peace
> And silence did await upon these thoughts
> That were a frequent comfort to my youth"
>
> (*Prelude* A, VI. 130).

Here the "Surpassing Life," "nor touched by welterings of passion" may be compared with the "Upholder of the tranquil Soul" in (*b*). In the later version the

" paramount endowment in the mind " is reduced to " paramount belief " and the " Surpassing Life " is further removed from " finite natures " by the addition of the lines,

" to the boundaries of space and time,
Of melancholy space and doleful time,
Superior, and incapable of change."

The distance between God and Man is widened again.

(*e*) After describing the break in the mist during the ascent of Snowdon (*Prelude* A, XIII. 67) he tells us:

" A meditation rose in me that night
Upon the lonely Mountain when the scene
Had pass'd away, and it appear'd to me
The perfect image of a mighty Mind,
Of one that feeds upon infinity,
That is exalted by an underpresence,
The sense of God, or whatsoe'er is dim
Or vast in its own being."

In the later version this " sense of God " becomes " recognitions of transcendent power," and the vital conception of an " underpresence " is eliminated altogether.

(*f*) In a MS. notebook are some lines which Professor de Selincourt prints in his edition (in the notes, p. 512). In these Wordsworth refers to the

" forms and images
Which float along our minds, and what we feel
Of active or recognizable thought,"

and states his belief that these are not " our being;"

" Such consciousness I deem but accidents,
Relapses from the one interior life
That lives in all things, sacred from the touch
Of that false secondary power by which
In weakness we create distinctions, then
Believe that all our puny boundaries are things
Which we perceive and not which we have made;
In which all beings live with god, themselves
Are god, Existing in the mighty whole, . .

 . .

As indistinguishable as the cloudless East
At noon is from the cloudless West, when all
The hemisphere is one cerulean blue."

The "false secondary power" has been incorporated in *Prelude* A, II. 216 (quoted above), but the rest of the draft remained in MS.

From all these passages together and specially from the last, the most explicit of all, it is possible to obtain a clear view of Wordsworth's experience; he tells us honestly what he felt in his moments of vision or ecstasy, without any thought of the inferences or deductions. When he came to review this experience and the language he had used in describing it, he realised what inferences and deductions might, inevitably would, be made. He was not prepared to honour those conclusions, to acknowledge them as his "system." A system "in which all beings live with god, themselves are god"—that was Pantheism! And Pantheism meant the negation of God as defined by current theology and the Church.

Such was the problem facing Wordsworth as he set about his philosophical poem. It was no new one, but before he had been able to leave it unsolved in the eager composition of his lyrics, expressing his feeling of joy in nature,

"Contented if he might enjoy
The things which others understand."

In those happy days of infinite speculation in company with the volatile mind of Coleridge he had ranged through the mystic philosophers, and in all of them there was a tendency to some form of Pantheism if one examined them with logical criticism. Hazlitt (*Spirit of the Age*, 1825) tells us what Coleridge was reading: Hartley's "tribes of the mind," his "vibrations and vibratiuncles and the great law of association that binds all things in its mystic chain"; Cudworth, Malebranche, the

Platonists old and new. And what Coleridge read, he talked about, and what Coleridge talked about, Wordsworth brooded on and transformed in his own language. The two friends were attracted by the root idea of Pantheism; the simile of the *Aeolian Harp* is a favourite one with both of them at this time. In his lines with that title (1795) Coleridge asks

> "And what if all of animated nature
> Be but organic Harps diversely fram'd,
> That tremble into thought, as o'er them sweeps
> Plastic and vast, one intellectual breeze,
> At once the Soul of each, and God of all?"

A reminiscence of this occurs in Wordsworth's account of his walk to Racedown in the first book of the Prelude;

> "my soul
> Did once again make trial of the strength
> Restored to her afresh; nor did she want
> Eolian visitations."

Again in *Religious Musings* (1794) Coleridge addresses,

> "Contemplant Spirits! Ye that hover o'er
> With untired gaze the immeasurable fount
> Ebullient with creative Deity!
> And ye of plastic power, that interfused
> Roll through the grosser and material mass
> In organizing surge! Holies of God!
> (And what if monads of the infinite mind?)"

How strangely, yet how characteristically of S.T.C., that metaphysical line is tacked on to the Miltonic apostrophe! Wordsworth's adaptation of Coleridge's thought may be found in the famous passage of *Tintern Abbey* and again in the Prelude A (I. 465) where instead of "Contemplant Spirits!" he addresses

> "Ye Presences of Nature, in the sky
> And on the earth! Ye Visions of the hills!
> And Souls of lonely places!"

These, haunting him among his boyish sports,

> "did make
> The surface of the universal earth
> With triumph, and delight, and hope, and fear
> Work like a sea."

Few examples could be found better to illustrate the way in which Wordsworth reproduces and transforms in his own more emotional and concrete language the intellectual conceptions of Coleridge.

But in finding a way of escape from Pantheism while retaining his conviction of a life in things, a soul divine which we participate, Coleridge could not help him. Those very lines which we have quoted Coleridge brands, in the same moment as he utters them, as "shapings of the unregenerate mind," and prays that

> "never guiltless may I speak of him,
> The Incomprehensible! save when with awe
> I praise him, and with Faith that inly feels;"
>
> (*Aeolian Harp.*)

There was no help in Coleridge. As early as 1802 he had lost all his joy in

> "nature and the language of the sense";

he had come to believe,

> "we receive but what we give,
> And in our life alone does Nature live . . . .
> We in ourselves rejoice!
> And thence flows all that charms or ear or sight,
> All melodies the echoes of that voice,
> All colours a suffusion from that light."

This would never do for Wordsworth. He could not renounce thus

> "the mighty world of eye and ear,"

the active life in nature; that would be fatal to his whole faith. Yet how to reconcile this faith with the teaching of the Church? When he wrote *Tintern Abbey*, the draft

of the *Prelude* and the *Ode on Intimations of Immortality from Recollections of Early Childhood*, he had been concerned merely with expressing his own feeling. And he had felt—it is clear from all the passages quoted—that man is, by right of nature and not through any added act of grace, a divine being, a participator with the whole world of nature, animate and inanimate, in the life of God. It might be shown that such a belief is not contrary to the teaching of Christ; that, indeed, it is in accord with the most vital of His recorded sayings, such as

"The Kingdom of God is within you."

What are these if not exhortations to realise the divinity in ourselves and to live habitually in the strength of this knowledge? However, the question whether Wordsworth's early faith is consistent with Christianity as taught by Christ, is one for the theologians to decide; there is no doubt that it was inconsistent with Christianity as taught by the Church of England in the nineteenth century; I have little hesitation in saying that it would be repudiated as a dangerous heresy by that Church now. This was a serious consideration for Wordsworth. Remember that he claimed to be a teacher; his poetry was to console the afflicted, to guide the simple. During the years that succeeded his first settlement at Grasmere he had opportunities of seeing how intimately the Church as a national institution entered into the common life of the people among whom he lived. Let us not here join in the gibe that it was the "respectability" of the established religion, his desire to stand well with the temporalities and powers, (his brother Christopher was moving upward in the ecclesiastical hierarchy), that influenced Wordsworth and induced him to make those alterations in the MS. of the *Prelude*. One has only to read the *Excursion* to see how his own feeling had changed between 1806 and 1814. Partly, this change was due, as I have hinted, to his

perception of the social value of the Church, its civilizing influence, as well as of the very real comfort afforded by its dogmas and sacraments to those who accepted and used them. As an institution it was a substantial part of the fabric of national life; its history was inseparable from the history of England, as his friend Southey was to show in his *Book of the Church* (1824). From shore to shore the steeple-towers and spires spoke to the "thronged abodes of busy men" and the "rustic wilds" alike as symbols of the spiritual world. As he thinks of them he exclaims,

> "may ne'er
> That true succession fail of English hearts,
> Who, with ancestral feeling, can perceive
> What in those holy structures ye possess
> Of ornamental interest, and the charm
> Of pious sentiment diffused afar,
> And human charity, and social love."
>
> (*Excursion*, VI. 23).

Partly, there was a change—deterioration, if you will—in his inward feeling. In the *Ode* he had lamented how the shades of the prison-house begin to close upon the growing Boy and the years bring the inevitable yoke. It is

> "the most difficult of tasks to *keep*
> Heights which the soul is competent to gain"

The conviction of "spiritual sovereignty" had been shaken by the experience of life, till all he can confess in 1814 is,

> "Man is of dust; ethereal hopes are his."
>
> (*Excursion*, IV. 138—140).

The Ode to Duty (1805) reveals the beginning of the process which is shown completed in the inscription *Near the Spring of the Hermitage;*

> "Troubled long with warring notions
> Long impatient of Thy rod,
> I resign my soul's emotions
> Unto Thee, mysterious God!" (1818)

No wonder then that looking back to the draft *Prelude* he now found it not completed "in such a manner as to satisfy his own mind." His philosophical poem was designed to show how exquisitely the individual mind is fitted to the external world, and how exquisitely, too, the external world is fitted to the mind. He might claim to have shown that by the record of his experience in the poems and in the *Prelude*: but a philosophical poem must go further and give some metaphysical theory of the connection. The metaphysical basis upon which, apparently, he had been building seemed to him, now that he came to examine it, too pantheistic in appearance. He had to find a theory that should account for the existence of a real life in nature and in man and the possibility of complete interaction or communion between them, while preserving distinct from either the life of God, who should be presented as influencing, controlling the life of man and nature, imparting, indeed, that life to them, yet—and this was the danger-point—not as identical with either of them.

He found, I suggest, the clue for which he was looking in the history of the conception of motion. He might well be led to this by reflection on the language in which he had himself attempted to speak of the one great life in man and things. Is not motion the one attribute of that life which appears most prominently in all the passages where he describes it, from the simplest lyrical utterance to the most impassioned outbursts of mystical fervour?

> "To her fair works did Nature link
> The human soul that through me *ran*";

> "Authentic tidings of invisible things;
> Of ebb and flow, and ever-during power;
> And central peace, subsisting at the heart
> Of endless agitation."

> "The mist, the shadows, light of golden suns,
> Motions of moonlight, all come thither—touch,

And have an answer—thither come and shape,
A language" . . .

"And all
That I beheld *respired* with inward meaning"

"A motion, and a spirit, that impels
All thinking things, all objects of all thought
And rolls through all things."

Now we know from the *Prelude* (VI. 115, a portion of which is quoted above) that in his undergraduate days he was interested in "geometric science" and specially delighted with

"that clear Synthesis built up aloft
So gracefully, even then when it appear'd
No more than as a plaything, or a toy
Embodied to the sense, not what it is
In verity, an independent world
Created out of pure Intelligence

(*Prelude* A, VI. 162).

Notice the "even then"; evidently he came to value this "Synthesis" more in later years. The same increase of respect may be found in his references to Newton, the greatest figure in this history of the conception of motion. Wordsworth has not much to tell us about the intellectual influences of Cambridge, but he does mention the effect upon his mind of living where "spiritual men" had moved, and first of these spiritual men he mentions

"Even the great Newton's own ethereal self."

That adjective "ethereal" is significant as we shall see later. Again he recalls his bedroom in St. John's College whence he could see the statue of Newton in the antechapel of Trinity. In the first draft (*Prelude* A, III. 58) the impression was fresh and he gives particular details;

"And, from my Bedroom, I in moonlight nights
Could see, right opposite, a few yards off,
The Antechapel, where the Statue stood
Of Newton, with his Prism and silent Face."

On revision, in accordance with his usual practice he cuts out these particular details "right opposite" and "a few yards off," but adds two lines—among the best in the whole poem—which indicate, I suggest, that his appreciation of Newton had deepened.

> "And from my pillow, looking forth by light
> Of moon or favouring stars, I could behold
> The antechapel where the statue stood
> Of Newton with his prism and silent face,
> The marble index of a mind for ever
> Voyaging through strange seas of Thought, alone."
> (*Prelude* B, III. 58).

In the interval between the draft and the revision Wordsworth too had been voyaging through strange seas of Thought, and in that voyage he had found, I believe, a chart to steer by in the work of Newton. For Newton's problem had been similar to his own. Let us briefly summarize it to show the similarity. In the physical philosophy of the eighteenth century there were, roughly speaking, two views of the relation of God, the creator, to the universe, the creation—Natura naturans and Natura naturata. According to the one view, represented by Leibnitz, God makes the world and then allows it to run as a machine runs. The Supreme Being is regarded "as bearing the same relation to the Universe as a watchmaker bears to a watch." According to the second, represented by Descartes and Boyle, God intervenes to keep the machine working, or to continue the metaphor, is constantly winding up the watch and oiling its parts.

Newton, as a theist and a churchman, deeply interested in theological speculations, rejected this conception of the Universe as a machine. For him the whole universe was directly animated by God present in every part of it. In the *Optics* (Query 28) he speaks of God as "a Being incorporeal, living, intelligent, omnipresent, who, in infinite space, as it were in his Sensory, sees the things

themselves intimately, and thoroughly perceives them and comprehends them wholly by their immediate presence to himself." A recent writer, Mr. A. J. Snow, from whose book on "*Matter and Gravity in Newton's Physical Philosophy*" these excerpts from Newton's works are taken, sums up his position thus: "As man has a consciousness which is his Sensorium of action, so God has a soul which is space. But as 'God needs no particular organ to operate' as the human soul does, God and His divine Sensorium are the same; God becomes the 'Soul of the World," being immediately substantially present everywhere—although Newton tried to guard himself against Pantheism."

When Newton, at the end of his *Principia* comes to a metaphysical as distinguished from the mathematical theory of gravity, he rejects the Cartesian conception of Motion as an attribute of matter,—a mechanistic conception at variance with his view of God as "a powerful ever-living Agent who being in all places is more able by his will to move the Bodies within his boundless uniform Sensorium and thereby to form and reform the Parts of the Universe." He puts forward, instead, the hypothesis of an immaterial principle or ethereal spirit (effluvium) as the cause of Motion. "Hitherto," he writes, "we have explained the phenomena of the heavens and of our sea by the power of gravity, but have not yet assigned the cause of this power. This is certain that it must proceed from a cause that penetrates to the very centres of the Sun and planets without suffering the least diminution of its forces. . . . And now we might add something concerning a certain most subtile spirit which pervades and lies hid in all gross bodies by the force and action of which spirit . . . bodies attract . . . cohere . . . Seeing, therefore, the variety of motion which we find in the world is always decreasing, there is a necessity of conserving and

recruiting it by active Principles, such as are the cause of Gravity." Reading the words of Newton and recalling the words of Wordsworth, I am led, not fancifully I trust, to the conjecture that when Wordsworth was seeking for a metaphysical theory of his perception of the universal life as "a motion and a spirit that impels all thinking things, all objects of all thought, and rolls through all things," he found it in Newton. Like Newton he rejected the watchmaker conception of God; he was aware of a life in things, he had *felt* and *seen;* like Newton, again he wished to guard himself against the charge of Pantheism. Is it improbable, therefore, to conjecture that he saw in these "active principles" of Newton the hypothesis that would solve his problem? Consider the impressiveness of the reference to Newton in the *Prelude;* does it not seem that there is a special significance in the adjective "ethereal" applied to him, reminiscent of his hypothesis of "ethereal spirits," the term which he uses elsewhere for the "active principles" in the passage quoted? Consider again the language of that passage,—"subtile spirit," "pervades," "lies hid in all gross bodies"—is it not the very language which Wordsworth uses again and again? Surely, if he went back to read Newton again, as I believe he did, after writing the draft of the *Prelude* and before writing the *Excursion,* he would find that language congenial and the theory it enunciates appropriate to his purpose. And he uses that theory, I believe, in the one passage in all his work in which he attempts to give a formal explanation. Elsewhere he is recording, as I have re-iterated, his experience, telling us what he has seen and felt. In the *Excursion* he begins the real work of his philosophical poem, to explain the relation between Man and Nature. And there is one passage in the *Excursion* which contains all that he has to give us of formal explanation. It stands at the beginning of the

final (9th) book, and is evidently intended to be the climax. The varying discourse of the Wanderer, the Solitary and the Pastor prepare the way for it, and the excursion on the lake with its combination of beautiful scenery with human incidents provides the setting. It is the Wanderer, *i.e.*, Wordsworth dramatized, who speaks.

> "as One
> Who from truth's central point serenely views
> The compass of his argument."

The 8th book closes with this preparation, and the 9th opens with the following lines,

> "'To every Form of being is assigned,'
> Thus calmly spake the venerable Sage,
> An *active* Principle:—howe'er removed
> From sense and observation, it subsists
> In all things, in all natures; in the stars
> Of azure heaven, the unenduring clouds,
> In flower and tree, in every pebbly stone
> That paves the brooks, the stationary rocks.
> The moving waters, and the invisible air.
> Whate'er exists hath properties that spread
> Beyond itself, communicating good,
> A simple blessing, or with evil mixed;
> Spirit that knows no insulated spot,
> No chasm, no solitude; from link to link
> It circulates, the Soul of all the worlds."

Both in the language of this passage and in its thought, there is evidence, I submit, for the indebtedness of Wordsworth to Newton, and this is the only passage in which he attempts a philosophical explanation of his belief. In it he achieves, as far as it could be achieved, the reconcilement of that belief with orthodoxy. The active principle, which subsists in all things and circulates from each to each is *assigned* to every Form. In this way he avoids the identification of God with Nature, while providing an explanation of our feeling of participation in the life of Nature. He goes on subsequently to apply this explana-

tion to his favourite theme by showing, as the argument prefixed to the book has it, " How lively this principle is in Childhood—Hence the delight in old age of looking back upon Childhood."

With this explanation the great philosophical poem comes to an untimely end. He must have felt it was inadequate; he intended to proceed with his poem,—Dorothy's letters show that,—but doubtless he realised more and more as time went on that his first instinct was right; he must be contented to enjoy; let others understand. In attempting the great theme he had essayed in his philosophical poem he was setting out on strange seas of thought, and he feared the currents might lead him to regions still stranger. He put back to port. " It is not the Author's intention formally to announce a system." His biographers record that Wordsworth had little sense of humour; but was there not, perhaps, a smile on his austere face when he penned that conclusion to his preface " the Reader will have no difficulty in extracting the system for himself? "

"SEND TO COVENTRY": A NOTE

BY

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There are many phrases in common use; while their meaning is clear, their origin is uncertain. One of such phrases is "send to Coventry." It is frequently used by many persons who know Coventry only perhaps as a centre of bicycle manufacture! Murray's New English Dictionary, that monument of industry and accuracy, has the following entry under this phrase:

> "To exclude him from the society of which he is a member on account of objectionable conduct; to refuse to associate or have intercourse with him. So also 'to be in Coventry.' [The origin of the phrase has been the subject of numerous ingenious conjectures. . . . A probable suggestion refers to the circumstances recorded in quot. 1647; a less likely source has been suggested in quot. 1691.]
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> 1647. *Clarendon*, Hist. Reb. VI. §83. 'At Bromigham a town so generally wicked that it had risen upon small parties of the King's, and killed or taken them prisoners and sent them to Coventry [then strongly held for the Parliament].'
>
> 1691. *Baxter*, in Relig. Baxt. 1. 1. 'Thus when I was at Coventry the Religious Part of my Neighbours at Kidderminster that would fain have lived quietly at home, were forced to be gone, and to Coventry they came.'"

It will be seen, thus, that the earliest reference recorded above is in Clarendon, 1647. The alternative origins suggested hardly seem convincing. During my reading of the Interludes, I came across a passage which probably suggests the real origin. The passage occurs in the *Interlude of John the Evangelist.* Yuell Counsayle says in this to Idelnesse:

"For sythe I came fro Rochester
I have spente all wynnynge
By our Ladye I wyll no more goo to Coventry
For there knaves set me on the pyllery
And threwe egges at my hede
So sore that my nose dyd blede."

On grounds of typographical style, the British Museum Catalogue fixes the date of this at circa 1565; but there is other evidence to suggest that *John the Evangelist* cannot be dated later than 1557. The reference, so early, to Coventry as a town where one had eggs thrown at one's head so sore that one's 'nose dyd blede' indicates an earlier and another origin than those mentioned in the *N. E. D.* It is hardly likely that the reference in the passage can be to the Coventry Cycle of Miracle Plays or to the Coventry Mysteries, for the speaker, Yuell Counsayle, goes on to speak boastfully of his wanderings over

"Englande thorowe and thorowe
Vyllage towne cytie and borowe."

SECTION II.

LAW.

THE MUSLIM LAW OF LEGITIMACY AND SECTION 112 OF THE INDIAN EVIDENCE ACT

BY

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The conflict between the principles of the status of legitimacy under the Muhammadan law and the provisions of section 112 of the Indian Evidence Act is well-known to all lawyers. We are not here concerned with the merits of either of the Muslim law of legitimacy or that of section 112; we propose to examine the correctness of the view held by the Allahabad High Court (48 All., p. 625, 1926, Sibt Muhammad *v.* Muhammad Hameed): " On a question whether a Muhammadan child born within six months of the marriage of his parents was to be considered legitimate, section 112 of the Indian Evidence Act 1872 applied and the child was legitimate." This decision is of importance, it is against the fundamental principles of the Muslim law as administered by the Courts in India. There is no doubt that section 112 [1] of the Indian Evidence Act has introduced the doctrine of *legitimatio per subsequens matrimonium.* But this doctrine is not recognised by the Muslim law.[2] Section 112 adopts the period of

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[1] Section 112 is as follows: " The fact that any person was born during the continuance of a valid marriage between his mother and any man, or within two hundred and eighty days after its dissolution the mother remaining unmarried shall be conclusive proof that he is the legitimate son of that man unless it can be shown that the parties to the marriage had no access to each other at any time when he could have been begotten."

[2] Ameer Ali, Muhammadan Law, vol. II, p. 234: " Section 112 of the Indian Evidence Act embodies the English rule of law and cannot be held to vary or supersede by implication the rules

birth as distinguished from the period of conception as a deciding factor in determining legitimacy. In other words a child not conceived in lawful wedlock is legitimated by subsequent marriage. However, in the Muslim theory of jurisprudence the question of legitimacy is to be determined with reference to the period of conception and not to the birth of the child. That is, the issue must be conceived in lawful wedlock to render it legitimate.

According to the Muslim law the following conditions are essential to establish legitimate descent:—	Section 112 of the Indian Evidence Act lays down the law thus:
1. There must be a lawful marriage, that is *sahih* and not *batil* (void) and in the case of *fasid* marriage the issue is also considered legitimate.	It assumes the existence of a valid marriage and a child born during its continuance is therefore legitimate, e.g., a child born say one day after marriage is legitimate.
2. The child must be born six months from the date of marriage in the case of *sahih* marriage and in the case of *fasid* marriage the period of	

of Muhammadan law . . . . . . the Muslim law does not recognise the doctrine of *legitimatio per subsequens matrimonium*."

Allahdad Khan's case, 10 All., p. 289 (on page 342): "No such rule is known to the Muhammadan law and we should really be introducing doctrines foreign to that system if influenced by the analogies furnished by the Roman, the French or the Scotch law of legitimation, we were to place acknowledgment of parentage under the Muhammadan law on the same footing as the rule of legitimation *per subsequens matrimonium* rests on in the foreign systems of law."

six months is to be reckoned from after consummation of marriage.

According to the Shiah law the child must be born six months from the date of consummation of marriage.[1]

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[1] The Holy Koran has thus fixed the minimum period of six months.

Holy Koran (Maulvi Muhammad Ali, p. 802 and p. 969):—

Part XXI, ch. XXXI, Verse 14: "And we have enjoined on man in respect of his parents—his mother bears him with faintings upon faintings and his weaning takes two years saying, Be grateful to Me and to both your parents to Me is the eventful coming."

ووصينا الانسان بوالديه حملته
امه وهنا علي وهن و فصله
في عامين ان اشكرلي ولوالديك
الي المصير

Part XXVI, ch. XLVI, verse 15: "And we have enjoined on man the doing of good to his parents, with trouble did his mother bear him and with trouble did she bring him forth and the bearing of him and the weaning of him was thirty months."

ووصينا الانسان بوالديه احسانا-
حملته امه كرها ووضعته كرها-
وحمله وفصله ثلثون شهرا-

What is the earliest viable age? Dr. Lyon (Medical Jurisprudence, p. 279) says: "(1) That there is no doubt but that a child born at or after the 210th day of uterine life may be reared; and (2) that the evidence afforded by recorded cases so strongly supports the view that children born as early as the 180th day may be reared, that the possibility of this cannot be denied. As regards the question of viability before the 180th day it should be noted that the validity of the evidence afforded by cases cited to prove

3. The natural period of gestation[1] is nine to ten months. This is the rule of Shiah law also.	It limits the period of gestation to 280 days after the dissolution of marriage so as to render the child legitimate.
4. Absolute non-access is a good ground for disclaiming paternity and further by the procedure of *li'an* the husband can also disclaim paternity of a child born to his wife.	It considers absolute non-access to each other as the only ground to establish illegitimacy.

If we hold that section 112 supersedes the Muslim law, some interesting results follow. Section 112 contemplates marriages into two divisions that is valid or void, while the Muslim law subdivides marriages into three categories, i.e.,

Section 112 and valid marriage.

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early viability mainly depends on the accuracy with which the date of conception is determined." Dr. Outrepont mentions a case in which a viable child was born 175 days after the last menstruation. The famous Jardine's case is the rearing of a 174-day child. The period of six months fixed by Muslim law is after all not ridiculous, though it should be noted that the Koran has not exactly fixed the earliest viable age, it is inferred from the above two passages of the Koran, *viz.*, the period of 2 years and that of 30 months, on subtraction we get six months. According to the Fatawa-Kazi Khan the months are reckoned with reference to the moon, hence the period need not be full 180 days.

According to the Code Napoleon the shortest period is 180 days.

[1] According to Imam Abu Hanifa the maximum period of gestation is 2 years; this is with a view to cover abnormal cases. The Maliki jurists had fixed 4 years but in Algeria Kazis administering Maliki law have adopted ten months. Vide Ameer Ali's Muhammadan Law, vol. II, p. 224. D'Ohsson, Tableaux Gen. de l'Empire Othoman, vol. III, pp. 102-3.

The Code Napoleon, Art. 312, has fixed 300 days.

'*sahih* (valid), *fasid* (irregular) and *batil* (void). It follows thus that the fine distinction maintained in the Hanafi system between *sahih*, *fasid* and *batil* marriages must cease to exist, and they must be made to fit into two categories either valid or void. Our difficulty is further augmented when we come to realise that there is no definition of valid marriage given in the Evidence Act.

However it will be granted that in every case the test of validity of marriage will be determined in accordance with the personal law of the parties; that is, in the case of the Muslims their personal law would be applicable. For instance, no Court of law would hold a marriage of a person with his own sister as valid in spite of the ceremony of marriage, for it is within the prohibited degree. A married woman that gave birth to a fully developed child, say within a month from the date of her marriage, was pregnant long previous to her marriage. According to section 112 such a child is considered legitimate, but for section 112 to apply the marriage must be a valid marriage. Hence the question simply resolves itself into a simple proposition whether marriage with a pregnant woman is lawful under the Muslim law? According to the Muslim law it is unlawful to marry a pregnant woman when the author of the pregnancy is known; in other words, when it is known by whom the woman has been rendered *enceinte*, nobody is to marry her until delivery.

E.g., A is pregnant from B. And if A marries C, the marriage is void. However a person who has rendered a woman pregnant may lawfully marry her.

The Fatawa-i-Alamgiri says:

It is unlawful to marry a pregnant woman when the author of pregnancy is known. But if a man marries a pregnant woman, then

تاوى عالمگيري جلد ثاني
كتاب النكاح
وحبلى ثابت النسب لايجوز
نكاحها...... يجوزان يتزوج
امرأة حاملا من الزنا ولا يطا
هاحتى تضع -

no cohabitation is permissible till delivery. However, if the person who rendered her pregnant were to marry her, then sexual intercourse is allowed.

The Fatawa Kâzî Khân says: A man marries a woman and then she gives birth to a full-grown child in less than six months from the time of marriage, then according to Imam Muhammad and Abu Yusuf the marriage is not valid.

فتاوى قاضي خان فصل في مسائل النسب-

رجل تزوج امرأة فجاءت بولد تام لاقل من ستة اشهر قال محمد رحمة الله تعالى النكاح فاسد في قولي وفي قول ابي يوسف رح

Mr. Shama Churun Sircar observed: "If a Muhammadan should have carnal connection with a woman, get her with child and then marry her; the child is not lawfully affiliated to him."[1] (Sharaya-ul-Islam.) The Hanafi jurists would however here introduce the rule of six months and hold that if the child was born after six months from marriage and the man does not proclaim or say that the issue was the result of previous illicit connection, then the benefit of doubt will be given to the child and it will be considered as a legitimate issue. But if the child was born within six months from the date of marriage then without any doubt the issue would be considered illegitimate.[2]

Mr. Ameer Ali has mentioned a very interesting case on this point:

"One Bakhta bin Yahya was married to Ahmad bin

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[1] Tagore Law Lectures, 1874, p. 273.

[2] As regards a woman who invariably commits *zina*, who lives the life of a prostitute, the accepted view is that if such a woman is married, then no matrimonial intercourse is allowed till her next period of menstruation so as to ascertain whether she was pregnant prior to her marriage or not.

Bayad on the 14th of April, 1864, three months after her separation from her first husband Abdul Kadir. On the 9th of July, 1864, she was delivered of a child. This circumstance came to the knowledge of the Kazi on the 13th of July. . . . He thereupon declared the marriage between Ahmad and Bakhta to be dissolved and their persons to be forbidden to each other according to the Maliki doctrine."[1]

Thus we see that for section 112 to apply, the validity of marriage would be determined according to the Muslim law, and in the majority of these cases marriages in which children were born within the period of six months from the date of marriage of their parents would be instances of invalid marriages. That is, the woman in those cases was not at that time a fit subject for marriage.

Of the writers on Anglo-Muhammadan law, we have already seen that Ameer Ali holds the opinion that section 112 cannot be held to supersede the Muslim law. Sir Roland Wilson is of the same opinion; he says, "The rule of the Indian Evidence Act, section 112 . . . is notwithstanding its place in the statute book a rule of substantive marriage law rather than of evidence, and as such has no application to Muhammadans so far as it conflicts with the Muhammadan rule that a child born within six months after the marriage of its parents is not legitimate."[2]

Mr. D. F. Mulla however holds the contrary view.[3] Mr. F. B. Tyabji is not definite on this point. The trend of his arguments has been throughout in favour of maintaining the Muslim law intact. But in his concluding

[1] Muhammadan Law, vol. II, p. 395.

[2] Anglo-Muhammadan Law (Digest), p. 161.

[3] Principles of Muhammadan Law, p. 135. This is an elementary book and Mr. Mulla has not considered the effect of upholding section 112 on the general law of marriage and inheritance at all.

remarks the learned author seems to support the contrary view. In fact there is a serious discrepancy between the same passage as printed in the 1st edition and that in the 2nd edition.

The text in the 2nd edition,[1] p. 267, is as follows:

> "It is difficult to resist the conclusion that the Indian Evidence Act, section 112, was drafted without giving a thought to a framework in which it would have to be set if it is to displace the Muhammadan law on this point. *But this oversight can hardly be a ground for disregarding its provisions.*"

This italicised sentence is thus expressed in the first edition,[2] p. 179, "It is almost as difficult to decide whether this oversight can be a ground for disregarding its provisions." There is a vast difference between these two sentences.

It is probable that at the time Sir Fitzjames Stephen drafted the Indian Evidence Act, the Muslim jurists of India were not consulted as to the framing of section 112. It seems to me that section 112 was drafted without giving a thought to the Muslim law of legitimacy.

Section 1 of the Indian Evidence Act says that, "It extends to the whole of British India and applies to all judicial proceedings in or before any Court." This passage itself suggests that its provisions were not intended to supersede any substantive rule of law except those governing judicial proceedings. The Muslim law of legitimacy is an integral part of the Muslim law of marriage and inheritance. This was the view expressed by the three judges in Muhammad Allahdad's case 10 All., 289 (1888), and discussing the Muslim law of acknowledgment of parentage Mr. Justice Straight held: "Now I do not

[1] Principles of Muhammadan Law.

[2] Ibid.

hesitate to say having very carefully considered the language of their Lordships' judgment that they unhesitatingly adopt the view that the rules of Muhammadan law relating to acknowledgment by a Muhammadan of another as his son or daughter as the case may be are rules of substantive law. . . . ."[1]

And in the same case on page 339 Mr. Justice Mahmud referred thus to section 112. "It may some day be a question of great difficulty to determine how far the provisions of that section are to be taken as trenching upon the Muhammadan law of marriage, parentage, legitimacy, and inheritance, which department of law under other statutory provisions are to be adopted as the rule of decision by the Courts in British India. Fortunately the difficulty does not arise in this case." We all know that those statutory provisions which make it incumbent on the Courts in British India to administer the Muslim law are posterior in date to the Indian Evidence Act, hence in the case of direct conflict the Muhammadan law should be upheld. It is a well-established presumption that subsequent enactment do not override prior ones unless they profess to abrogate the previous provisions.

There is a case reported in the Indian Cases, vol. 43, p. 883 (1917), decided by Mr. Stanyon, Judicial Commissioner, Nagpur, in which the learned Judge comes to the correct view that "Neither paternity nor legitimacy can be obtained by adoption and a child begotten by *zina* cannot be made legitimate by subsequent marriage of its parents before its birth, section 112 of the Indian Evidence Act being inapplicable to Muhammadans." This is a reported case prior to the decision of the Allahabad High Court (48 All., p. 625), but it was not noticed by the Hon. Judges.[2]

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[1] 10 All., 289.

[2] The learned judges observe, on page 628, "The question

Section 112 and *fasid* marriages.

So far I have not discussed what would be the effect of section 112 on the *fasid* marriages of the Muslim law. We have noticed that as regards *sahih* marriages the rule of six months is to apply after the date of marriage, but in the case of *fasid* marriages this rule is to apply after actual cohabitation. The rule operates more strictly in the case of *fasid* marriages. In the case of a *fasid* marriage *iddat* and dower becomes obligatory only after cohabitation (prior to that it is treated as devoid of legal consequences) and the issue of the union subject to the six months' rule is considered legitimate.

Now if section 112 were to apply to *fasid* marriages also, then the well-recognised distinctions between *sahih* and *fasid* marriages would automatically cease to exist. This point also came before the Court for the first time in a case in 1926 and happily the judges of the Chief Court, Lucknow, have decided it correctly (Musammat Kaniza *v.* Hasan Ahmad, The Indian Law Reports, Lucknow Series (1926), Vol. I, p. 71).

The Court held that "Section 112 of the Evidence Act cannot be applicable in any way to the marriage which is neither void *ab initio*, *batil* nor absolutely void but is *fasid*, *i.e.*, irregular, inasmuch as section 112 is based on a division of marriage into two categories (valid and invalid) and cannot be applicable to Muhammadan Law which divides marriages into three categories, *viz.*, *void ab initio* (*batil*), *fasid*, and valid. In any case if section 112 can be held applicable, then the word 'valid' in that section should be construed as 'flawless' so that the presumption would not apply to *fasid* marriages."

Consequently my conclusion is that section 112 of the

how far section 112 of the Evidence Act is to be taken as overriding the rules of Muhammadan Law does not seem to have been determined in any reported decision." Vide also Hajira Khatun *v.* Amina Khatun, 73 I. C., p. 982.

Evidence Act should not be held to apply to *sahih* and *fasid* marriages contracted under the Sunni Law.

Section 112 and the Shiah Law.

Let us proceed to examine the effect of holding that section 112 supersedes the Shiah law of legitimacy. The Shiah jurists divide valid marriages into two categories: (1) permanent marriages, (2) temporary marriages *muta'*. We know that a *muta'* marriage is radically different from permanent marriages, for *muta'* is contracted for a fixed time or period, *e.g.*, for a day, month, or for two years. While a Muslim cannot marry more than four by permanent marriages, there is no limit fixed as regards *muta'* marriages. The *muta'* wife does not inherit at all.

There is no divorce in the *muta'* form of marriage.[1] Neither *ila* nor *li'an* is applicable to the *muta'* wife. The children are legitimate as in the case of permanent union. If section 112 is considered applicable to the *muta'* marriages, then the distinction between permanent and temporary marriages ceases to exist in the Shiah law. If not, then it follows that the Muslim law will apply to *muta'* marriages and section 112 only to permanent marriages. Thus there would be two different rules instead of the Muhammadan law of paternity.

In short it cannot be maintained that section 112 applies either to the Sunni law or to the Shiah law.[2]

So far we have analysed the application of the

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[1] But the marriage could be dissolved by the doctrine of the gift of the term.

[2] What about this peculiar case of the Shiah law cited by Mr. Shama Charan Sircar, Tagore Law Lectures, 1874, p. 274: "If a man should erroneously cohabit (with a woman who is a stranger) supposing the woman to be his wife or his slave and she should produce a child, its parentage is established in him." How is the case to be determined by section 112 of the Indian Evidence Act?

six months' rule with reference to section 112 of the Evidence Act; we proceed now to discuss the bearing of the other provisions of section 112 on the general Muslim law. Section 112 limits for conclusive presumption the period of gestation to 280 days after the dissolution of marriage to render the child legitimate. Now assume the child is born after 285 days, then under the Evidence Act it is a question of fact for the Court to determine whether it is illegitimate according to section 112; but according to the Muslim law of legitimacy such a child is undoubtedly legitimate. Because the Shiah jurists and majority of the Sunni jurists hold the maximum period to be ten months, the Code Napoleon has also fixed 300 days. It is not so easy to decide how long may human gestation be prolonged. Guy observes that of 14 authentic cases the minimum duration was 270 days, the maximum 293 and the average 284 days. According to Wharton and Stille, in 19 cases the duration was 280 days, in two cases it was 291 days, and in three 296 days. Dr. Lyon discussing the longest period of gestation points out that "it may be regarded as proved that this may be 296 days."

Period of gestation.

Most authorities agree in considering that the interval may be as long as 44 weeks or 308 days.

Some authorities consider that the interval may extend to the forty-sixth week, 315 to 322 days.[1]

Consequently even the natural maximum limit fixed by the Shiah jurists that of ten months and accepted by many of the Sunni jurists cannot be said to be conclusive and the Hanafi jurists in such abnormal cases fall back on the dictum of Imam Abu Hanifa that the birth must take place within 2 years after dissolution or divorce of the woman. However, from this we cannot argue that the

[1] Medical Jurisprudence, p. 277.
See also Taylor's Medical Jurisprudence, p. 60.

great Imam has fixed 2 years as the longest period of gestation because this rule is to be read together with the provision that while observing the period of iddat the woman must declare that she is pregnant. This fact is to be decided within the period of iddat. And if after declaration the woman were to continue *enceinte* and exceed the natural maximum limit of gestation, the case would then be fully covered by the 2 years' rule of Imam Abu Hanifa.

Here are two instructive cases from the Fatawa Kazi Khan:

A woman says during the iddat for the death (of her husband) "I am not pregnant" and then says (during the iddat) the day after "I am pregnant"; her latter word shall be accepted (and her iddat which in the event of her not being pregnant would have been four months and ten days will now extend to the period of delivery). But if she says after four months and ten days (which is the period of iddat for death) "I am not pregnant" and and then says "I am pregnant" then her latter word shall not be accepted (to establish her conception from the husband) except when she gives birth to the child at less than six months from the date of the death of her husband and

فتاوی قاضي خان فصل في مسائل النسب

امرأة قالت في عدة الوفاة لست بحامل ثم قالت من الغد انا حامل – كان القول قولها – فان قالت بعد اربعة اشهر وعشرة ايام لست بحامل ثم قالت انا حامل لايقبل قولها الان ثاني بولد لاقل من ستة اشهر من موت زوجها فيقبل قولها و يبطل اقرار ها بانقضاء العدة

then (that is, in the event of her giving birth as aforesaid) her birth shall be accepted (that is, the conception shall be regarded as from the husband) and her admission regarding the expiry of the iddat (involved in her expression that she was not pregnant made as above) shall be void (and the parentage of the child shall be established in her husband).[1]

" A woman has been divorced by her husband thrice and she is an Ayisa (or a woman whose monthly course has ceased); she then after a few months gives information (that is, expresses herself before the people) that her iddat which was reckoned with reference to months has expired; she then gives birth to a child (at more than two years from the divorce). Aboo Yusoof on whom be peace says her iddat shall expire by the birth of the child and the child shall not belong to the husband except when he claims the child.[2]

امرأة طلقها زرجها ثلثا وهي
آئسة فاخبرت بعد سثهوران
عدتها قدانقضت بالا شهر
ثم جائت بولدلاكثر من سنتين
قال ابويوسف رحمه اللهتعالي
تنقضي عد تها بالو لادة
ولايكون الولد للزوج الاان
يدعي

[1] Moulvi Mahomed Yusoof, Tagore Law Lectures, 1891-92, Vol. II, p. 136.
[2] Ibid., p. 135.

The rule of non-access, of Section 112 and the Muslim Law.

The rule of non-access is recognised by the Indian Evidence Act. It is also recognised by the Muslim law. Section 112 does not in terms refer to the presumption being rebutted if the husband be impotent. However access means sexual intercourse and it is negatived by the fact that the husband was impotent.

It is the rule of the English law that the declaration of a father or mother cannot be admitted to bastardize the issue born after marriage.[1]

In a recent case Warren *v.* Warren (1925) Probate, Divorce and Admiralty Division, p. 107, the Court held that "A wife's admission that she had committed adultery even if accompanied by a statement of her belief that a child subsequently born was the result of the adultery, cannot bastardize the child without evidence of the non-access of the husband." Both these rules are inapplicable, for the Muslim law gives an absolute power to the husband in those cases where it is difficult to establish non-access to disclaim the paternity of the child born in accordance with the procedure of *li'an*. If section 112 is held to supersede the Muslim law, then the procedure of *li'an* must cease to exist. "*Li'an*," says Baillie, "are testimonies confirmed by oaths on both sides referring to a curse on the part of the man which is a substitute for the *hudd-ool-kuzf* or specific punishment for scandal, and for *ghuzub* or wrath on the part of the woman which is a substitute for the *hudd-ooz-zina* or specific punishment for adultery."[2] When the husband accuses his wife of adultery, and when both have reciprocally made *li'an* then the husband has the option of divorcing his wife. If he refuses, then the Court must dissolve the marriage. The

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[1] Goodright's case per Lord Mansfield.

[2] Digest of Muhammadan Law, p. 335.

effect of *li'an* is that the paternity of the child born to the wife is not established.

E.g., A consummated his marriage with B. B within A's knowledge has committed adultery and issue is born to them.

The child's paternity is established in A; but he can disclaim it by *li'an*.

Strictly speaking the procedure of *li'an* is inapplicable in British India, unless the Court takes advantage of the Oaths Act X of 1873. However the Allahabad High Court has recognised the law of *li'an* and held that "A Muhammadan wife is entitled to bring a suit for divorce against her husband and to obtain a decree for dissolution of marriage on the ground that the latter has falsely charged her with adultery."[1]

The idea of legitimacy.

It is a peculiarity of the Muslim law that it permits the husband to disclaim a child born to him from a wife lawfully married. As a matter of fact legitimacy as understood by the Muslim jurists stands on a different footing to the conception of legitimacy under the English law or to that in section 112 of the Indian Evidence Act. According to the English law legitimacy attaches to the child, it fixes its relationship with both its parents. Whereas the Muslim law speaks of the relationship and of two distinct relationships, *viz.*, paternity and maternity.

Under the Sunni Law there is no such thing as an absolute illegitimate child, that is, a child is always legitimate to its mother. In other words, the so-called illegitimate child always inherits from the mother.

According to the English law the child of an unmarried woman is always a bastard, but under the Muslim law maternity cannot be disclaimed, whereas paternity admits

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[1] A.L.J.R., Vol. XVII, 78. Zafar Husain *v.* Ummat-ur-Rahman; also 41 All., p. 278. *Vide* a recent case where the law of *li'an* is discussed. Rahima Bibi *v.* Fazil, 48 All., p. 834 (1926).

of the possibility of being disclaimed. When the father has disclaimed a child, it does not affect its right of inheriting from its mother. This novel conception finds no place in the laws of marriage of any other legal system. Acknowledgment of paternity and the disclaimer of parentage are both fully recognised by the Muslim law.[1] As regards acknowledgment of paternity, the Muslim jurists maintain that the offspring of illicit intercourse cannot be acknowledged. This view has been recognised by the Privy Council and by the Indian High Courts.[2] Thus in no case can an illegitimate child benefit from his alleged putative father.

The Muslim law insists on the purity of conception—a child must be conceived in lawful wedlock. All *bonâ fide* cases of error or doubt, that is, all marriages contracted in ignorance of the fact that the woman was prohibited are instances of *fasid* marriages and the issue is accordingly legitimate, hence it can be said that to this extent the Muslim law disfavours bastardizing children. But it goes no further. A child if it is the result of fornication, adultery, incest, or of any description of illicit union is held illegitimate to his natural father but legitimate to his natural mother.

Finally, if section 112 is held to supersede the Muslim law of legitimacy, then it will affect not only the relation-

[1] However the right of disavowal is a "terminable right." As regards fixing the time regard is to be had to custom. Imam Abu Yusuf and Muhammad have fixed 40 days after the birth of the child; if the husband is on the spot during his wife's confinement then only a week's time is allowed by some of the Hanafi jurists and the Maliki allow only two days. The Shiah jurists allow 40 days.

[2] 10 All., p. 289, per Mahmud, J.: "A child whose illegitimacy is proved beyond doubt by reason of the marriage of its parents being disproved or found to be unlawful, cannot be legitimatised by acknowledgment."

ship of the child with his father but with other members of a family also. After all it may be granted that a natural father should support his issue irrespective of the fact that it is illegitimate or legitimate. But why should other members of a family be forced to admit a stranger socially condemned as their prospective heir, for the Muslim law of inheritance admits of minute division of property into shares and those sharers again have reciprocal rights of inheritance *inter se* under certain contingencies well known to lawyers?

In short the effect of the decision in 48 All. (p. 625) would be serious if followed by the other Indian High Courts.

SECTION III

PHILOSOPHY

SOME ASPECTS OF THE ABSOLUTISM OF SHANKARACHARYA

(A Comparison between Shankara and Hegel)

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PREFACE

Whoever has made an impartial survey of the present state of comparative philosophy must have been struck by its apparent lack of centrality. A confusing mass of interpretations none of which has the remotest chance of being reconciled with the rest, is made all the more perplexing by attempts, often very ingenious and flattering, to infuse the spirit of the latest systems of European philosophy into the old body of Indian metaphysics. The object of the comparative study in philosophy, we believe, is to discover the dialectic movements of universal thought; but this will remain a far-off dream or a mere pious wish till the different interpretations are dragged out of their subjective seclusion in the enjoyment of an oracular prestige into the region of objective criticism. What is wanted is a spirit of co-operation, and it is this spirit of co-operation which the following lines are primarily designed to foster. But it is a singular misfortune of the student of philosophy that he can seldom co-operate with another without opposing the latter's views; and in his speculative adventures in the region of Truth, he has often to put on the appearance of a dictator in spite of his real attitude being that of a humble enquirer. Hence, it is necessary to remark that opposition in the domain of philosophy is not a sign of disrespect; on the contrary, it is in certain cases the highest tribute to the speculative profundity of the opposed views.

INTRODUCTION.

Difficulties in the comparative method.

Of the many disadvantages which a modern exponent of an ancient system of thought has of necessity to encounter, there is perhaps none more subversive and ruinous than the tendency to get oneself entangled in the meshes of ideas originating from an entirely different type of thought and having implications that become altogether misleading when divorced from their historic context. It not only stands in the way of a full appreciation of what is unique and instructive in the old speculation, but it leads to more disastrous consequences, especially when the exposition proceeds on a comparative basis. Failing to accentuate those points in it which constitute its real strength, the immediate task of the interpreter reduces itself to finding a means of establishing its speculative claims at any cost. Far-fetched explanations, twistings and strainings are the inevitable results of such a procedure. Problems of philosophy, it is important to realise, are intimately connected with the spirit of the age and the intellectual tradition of a nation. This is true not only of the problems, it equally holds good of the nature of the methods employed and of the directions in which intellectual satisfaction is sought. This circumstance, however, does not render the comparative method futile in the domain of philosophy, nor does it militate against the essential identity of dialectical processes in different worlds of thought. It only indicates the abuses to which the comparative method is liable, and thus makes the task of the modern interpreter infinitely more difficult in this field than in other departments of enquiry.

The source of the difficulties is perhaps to be traced ultimately to the laws of development with which biological investigations have made us familiar. The principles of differentiation and integration which underlie

the growth of organic life and which have lighted the paths of investigations in the fields of psychology, sociology and many other allied sciences, have a very important bearing on the present subject. Our concepts, those intellectual moulds with which we have inevitably to work in philosophy, grow in definiteness and fixity with the progress of speculative efforts to solve certain problems. And in the intellectual struggle that is born out of these efforts only those concepts survive which prove most efficient in reconciling the conflicting demands of the age. Hence the danger of reading an old thinker in terms of the new. The external wrappings of a concept may continue unchanged long after its life has completely disappeared. The word 'idea' is a case in point. This term, as is well-known, though used by a long succession of thinkers, has still remained one of the most ambiguous in philosophy; the archetypal essence of phenomenal things, the Platonic meaning of the term, has very little in common with its modern meaning as phenomenon. Another important consequence of these intellectual struggles is to destroy the elasticity of the concepts by introducing sharper distinctions and more rigid niceties into their contents. Much of the obscurity which we find present in the previous systems of thought arises from the comparatively high differentiations of the conceptual organism which we bring to bear on their simple homogeneity. Spirit, matter, content, reason and many other concepts which are most in use in the philosophical speculations of our time are, by reason of the very preciseness of meaning which makes them valuable instruments in the hands of the modern critic, likely to lead to confusion of issues when pressed into the service of an interpreter of Greek philosophy. The entirely different interpretations which it has been possible to put, for instance, on the teachings of Parmenides are mainly due to the gulf which separates the modern

notion of pure being from the Eleatic conception of being; the confusion arises from the attempts at further determination, in the light of modern thought, of what was homogeneous and little differentiated by the original thinkers. To define it as the 'full,' the mass that fills space, is to introduce an amount of determinateness into the notion of being which is too much for its simplicity. Hence the monism of Parmenides and Heraclitus has been very aptly compared to the block of marble which may be formed into a basin or a Jupiter. In the absence of sharp distinctions in the Greek conceptions of spirit and matter, our modern notions with their highly differentiated contents are hardly enlightening when used for labelling the earlier speculations. The inadequacy of such terms as materialism and spiritualism to be fit titles for the pre-Socratic thoughts is evident from the fact that even the Aristotelian conception of soul has none of those associations which it has come to possess for us through the progressively refined discussions of later ages. After the Cartesian opposition of the extended to the thinking substance, it is no more possible for the modern thinker to identify the physiological conception of function with the psychological conception of mind.

How to remove them?

These difficulties, we must insist at the risk of repetition, do not make comparative study a mere pious wish in the field of metaphysical thinking. They signify the dangers of isolating the fundamental conceptions of a philosophy from their proper setting. It is then important to make sure, before we could hope to achieve anything of abiding speculative interest by drawing together two different expressions of human reflexion on the nature of Reality, that in the act of interpreting one system in terms borrowed from the other, its basic notions are carefully restored to their historic lineaments. The importance of these remarks can hardly be exaggerated when the systems compared are not

simply separated by a long interval of continued and progressively definite attempts at solving the world problems, but they belong to two entirely different intellectual traditions which ran their courses without mutual influence on each other. If then we want to profit by thinking modern problems of European philosophy in Indian terms without misrepresentation of either and yet with a considerable clarification of both methods of thought, we must give up the practice of finding Kant and Hegel, for instance, in the Upanishads; these are misrepresentations which do not clarify but confound problems. No one possessing a really unprejudiced insight into Indian philosophy will deny that there is an ample supply of valuable dialectical weapons in the armoury of the ancient Indian schools and that they are as good for offence and defence in the battles of modern philosophy as they were when they were first forged. But no intellectual victory can be won by their indiscriminate use. The problems of epistemology and the methods of proof which came to prominence with Kant and Hegel, were evolved under the pressure of circumstances radically different from any that could exist in India, and consequently we should be doing injustice to the speculative integrity of Indian philosophy if we had to expect from it satisfactory answers to even such problems of philosophy as, in the absence of similar conditions, could hardly engage the attention of the ancient thinkers.

Need of comparison.

This is not sufficiently realised by some of those who are otherwise doing inestimable service to the cause of national culture by rousing the curiosity and interest of the present generation in one of the oldest types of speculative efforts to decipher the mysteries of existence. The tendencies of modern comparative philosophy appear to be to bring Indian philosophy so close to its western namesake that they may be shown to have entered the same compartment

through exactly the same gateway. Thus, for instance, there is a persistent tendency in some of the modern interpretations of the Vedantic system to read into it all the problems and philosophic methods which have ever been present in the speculations of modern Europe, specially on the monistic lines. This is nothing unnatural. For, the type of absolutism represented in the Vedantic thought is generally supposed to be analogous to the abstract pantheism of the west and this fell into disrepute owing mainly to the massive influence the Hegelian philosophy commanded over the philosophical world of the nineteenth century. And there is no doubt that if the Hegelian contentions against abstract universalism be right, the Vedantic position will sustain an irreparable loss till it can be interpreted on other than the traditional lines. This is perhaps the reason why those who convinced of the finality of Hegelianism turn their gaze towards the native thought, have to begin by disclaiming its relation to abstract universalism and vindicate its affinities with what has been called higher pantheism. This nervousness, we are persuaded to believe, is altogether gratuitous, firstly because the finality of the so-called higher pantheism has been at least as often denied as asserted. In view of the fates which have been overtaking the metaphysical theories in the west during the last two thousand and five hundred years, the claims of finality in a reasoned system of thought can show nothing better than enthusiasm. Secondly, even supposing that philosophic wisdom reached the height of perfection in the German philosopher, we certainly deprive ourselves of the power of appreciating much that is valuable in the native lore by looking upon it as a briefer edition of Hegel's works. An attempt is therefore made here to bring together those features in occidental absolutism and Vedantism which have provided such alluring analogies between these two discontinuous streams of thought.

ORIGIN OF KNOWLEDGE

We may perhaps conveniently begin the enquiry by distinguishing the problems of knowledge from the world-views which follow from their epistemological conclusions. The charge of dogmatism which has frequently, and perhaps not unjustly when judged from the standpoint of the western conception of philosophy, been brought against Indian philosophy in general cannot be adequately met by pointing out that " most of the systems of philosophy in India discuss the problems of knowledge, its origin and validity, as a preliminary to the study of other problems."[1] A philosophy, in spite of its critical intentions, may be highly dogmatic in so far as it depends for its final view of Reality on a source of knowledge which is supposed to be superior to and even subversive of, the ordinarily recognised methods of acquiring knowledge. The appeal to the Vedas as the ultimate authority sitting in judgment upon the results of perception, reasoning and every other source of human knowledge, as is well known, is the differentiating mark of the so-called orthodox systems of Hindu philosophy. This cannot but strike those who are in the habit of respecting only rational pronouncements in the field of philosophical researches as something very disquieting and perplexing. The metaphysical value of the analysis of normal perceptual and inferential knowledge, howsoever acute and complete, is seriously impaired in the presence of the embarrassing reminder that the ultimate reality is not to be reached through any of these avenues of knowledge. The western thinkers of the middle ages, notwithstanding their efforts at rationalizing Christian dogmas, were dogmatic precisely for the same reasons, namely, an implicit faith in Revelation and a consequent

[1] Prof. Radhakrishnan, *Indian Philosophy*, Vol. I, p. 50. A similar view was entertained by Prof. Max Muller in *The Six Systems*, p. xii.

distrust of the unaided Reason. To urge therefore, that "the appeal to the Vedas does not involve any reference to an extra-philosophical standard[1] is extremely misleading till the place of Revelation in a reasoned system of knowledge is adequately explained."

REASON AND REVELATION

The relation between reasoned knowledge and revealed truths, as it is explicitly maintained in the scholastic philosophy of Europe as well as the orthodox systems of India, is one of antagonism or subordination. To parallel the scholastic beliefs that outside of the Church, there can be no salvation and no science, and that to philosophize is to explain the dogma, we have here such explicit expressions as that in the matter of Highest Reality whose knowledge is the *sine qua non* of emancipation, reasoning is an entirely unreliable support,[2] and that the superiority of the Vedanta consists in its being mainly an exegesis of the Vedas. Again, underlying the orthodox condemnation of the speculations of Charvaka, Buddhism and Jainism as heretical there are precisely the same reasons which led western scholasticism to discourage independent intellectual efforts after truth, namely, the reluctance of the heretics to identify philosophy with theology, the orthodox belief in the inherent limitations of our faculties of knowledge, etc. Lastly, as in scholasticism so in the history of Indian orthodoxy, efforts are frequently made to bring rationally reached conclusions into conformity with revelation by putting evidently forced interpretations either on the sayings of the original author of a system or the words embodying revealed truths; and equally frequently, these attempts at reconciling Faith with Reason culminate, by reason of their disappointing results, in a deep-

[1] *Ibid.*, p. 51.

[2] यद्यपि क्वचिद्विषये तर्कस्य प्रतिष्ठितत्वमुपलक्ष्यते, etc. Shankar's *Commentary on the Sutra*, I. 2. 11.

seated misology. The declarations that real knowledge is not to be acquired by those who aspire after merely intellectual triumphs, that rational discussions are meant for very ordinary people, and that no finality can be claimed for reasoned knowledge in view of the possibility of its being subverted by a more expert logician, are clearly indicative of a distrust of reason which recalls the scholastic spirit. Indeed, this misology sometimes appears to reach the very absurd height of the *Credo quia absurdum* of Tertullian, as e.g., in Kumarila Bhatta's avowed statement that contradictions in Smriti are nothing derogatory in so far as they are based on the contradictory statements of the Sruti (Tantra Vartika). A similar tendency in Vedantism is suggested by Dr. Deussen's observations that " it is possible occasionally to make such statements about the Brahman as would be, according to worldly standards, absolutely contradictory; for example that the Brahman does not wholly enter into the phenomenal world, and yet is without part."[1]

Now, if philosophy is reasoned knowledge or " the thinking consideration of things," it cannot conceivably be based on a source of knowledge which is so opposed to the ordinary sources that its deliverances should admit of being couched in palpably conflicting propositions. No thinking consideration of things, it may seem altogether superfluous to point out, can afford to ignore the fundamental laws of thought. The inevitable conclusion that follows from an impartial survey of this evidently anti-intellectual tendency, we venture to think, is that the appeal to the Vedas is nothing short of an extra-philosophical criterion. This circumstance, however, does not make the orthodox system a mere aggregate of independent isolated and mutually conflicting expressions. On the contrary, admirable attempts at systematization are

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[1] *The System of the Vedanta*, p. 93.

clearly visible not only outside but inside the Vedantic speculations. It has been rightly remarked that "Vedantism is not to be taken as philosophy based solely upon revelation or faith that has no rational justification . . . it is based upon the profoundest forms of thinking and argument."[1] A similar remark, however, applies to the philosophy of the Schoolman, which abounds in the subtleties of dialectics. Scholasticism in spite of these intellectual attempts at systematizing the dogmas of religion has been condemned as dogmatic owing to its appeal to a standard external to Reason; and we must bear in mind that the function of reason, according to the explicit statements of the Vedantic thinkers, is nothing higher than the refutation of heretical objections to the revealed wisdom and the exposition of "the real meaning of the apparently conflicting ideas of the Vedas."[2] It appears to be very significant that a thinker notwithstanding his implicit faith in an extra-rational source of knowledge should yet feel the necessity of so interpreting revelation as to bring it into conformity with the demand of reason for consistency. These attempts at rationalizing dogmas, whether in India or Europe, apparently involve a vicious circle. Though revelation is believed to have a higher authority than reason, yet reason sits in judgment upon revelation and makes it yield an account which would satisfy the demand of reason itself. That is, revelation which is believed to be the supreme norm of philosophic thought has to conform to reason, and to that extent must acknowledge the superiority of what is yet thought to have a derived and conditional authority.

REASON AND INTUITION

This appeal to a standard which is not only external to, but frequently subversive of, the natural means of

[1] Prof. M. Sircar, *The System of Vedantic Thought*, p. 2.
[2] Prof. Das Gupta, *History of Indian Philosophy*, p. 41.

knowledge is so opposed to our ordinary habits of thought, that the search for a *reason* in explication of this apparently irrational appeal is not infrequent in scholasticism as well as Indian orthodoxy. One of the most acceptable explanations is to refer the Scriptural Texts to a unique faculty of knowledge, generally called Intuition. Here we come upon a most characteristic feature of Indian speculations which has not received as much attention as it surely deserves in an unbiassed exposition of Indian thought and an unprejudiced critical study of methodological principles. It has passed into a truism that the different systems of Hindu philosophy, notwithstanding their divergences on many a vital point of real speculative interest, agree in insisting on the paramount importance of right knowledge as the indispensable condition of emancipation and the attainment of the Highest Good. But what we miss in the modern interpretations of Hindu thought is the proper emphasis on the unique characters of Indian epistemology. It is perhaps high time to insist that right knowledge which is made the indisputable corner-stone of philosophy here is conceived in a way so different from the epistemological conceptions of occidental philosophy that their fusion can lead to nothing better than unseeming hybrids.

Intuition in Nyaya.

For a proper appreciation of the characteristically Indian analysis of knowledge, we have necessarily to bear in mind the well-known passage of the *Brihadaranyaka Upanishad.*[1] *Shravan*, *manan*, and *nididhyasan*, as the three distinct stages in the attainment of true knowledge may be rightly claimed to be the unique feature of the Indian theory of knowledge; and the ancient philosophers, though they differed widely on their detailed analysis of the psychological factors involved in the

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[1] आत्मा वा अरे द्रष्टव्यः श्रोतव्यो मन्तव्यो निदिध्यासितव्यः ।

different types of cognition, accepted this methodological rule as one of the unquestionable certainties of philosophy. The important rôle which *nididhyasan* played in the ancient theories of knowledge may be easily realised from the way in which it is accentuated even in the Nyaya system that is generally supposed to be the least inclined to question the authority of the accepted avenues of knowledge. In the subtle analysis of our faculty of knowledge as it expresses itself in the manifold types of cognition, a high place is accorded to 'vada' which is distinguished from 'jalpa' and 'vitanda,' as being alone concerned with the determination of reality.[1] This emphasis on the 'vada' as a means of right knowledge which is characteristic of the Nyaya philosophy has evoked censorious reflection from the critics like Shankara who assign the philosophic advantage of Vedantism over Nyaya to its reluctance to accept reasoning as the supreme norm of knowledge.[2] Now, the really significant point which shows the essential unity underlying the superficial divergences of these systems in respect of the problems of knowledge is that Gotama, though fully realising the importance of rational arguments for the attainment of truth, is so convinced of the limitations of the ordinary sources of knowledge that he not only condemns them as illogical (न्यायाभासाः) so far as they are inconsistent with 'Sruti'[3] but actually relegates the function of certain types of reasoning to the

[1] The superiority of 'vada' to the other varieties of 'katha' is not only recognised within the Nyaya system, but it is actually deified by thinkers belonging to other schools of thought. Thus *eg.*, the Gita says, वादः प्रवदतामहम् 10, 32. This is explained by Shankara as वादोऽर्थनिर्णयहेतुत्वात्, प्रधानं, अतः सोऽहमस्मि । Similarly, Sreedhar Swami points out that, वादस्तु वीतरागयोः शिष्याचार्ययोरन्ययोर्वा तत्त्वनिरूपणफलः, अतोऽसौ श्रेष्ठत्वात् मद्विभूतिरित्यर्थः ।

[2] वेदान्तवाक्यानामैदम्पर्य्यं निरूपयितुं शास्त्र-प्रवृत्तन तर्कशास्त्रवत् केवलाभिर्युक्तिभिः कश्चित् सिद्धान्तं साधयितुं दूषयितुं वा प्रवृत्तं Shankara's Com. II. 2.

[3] यत्पुनरनुमानं प्रत्यक्षागमविरुद्धं न्यायाभासः स इति, Vatsyayana's Com. to I.1.1.

protection of truths against heretical onslaughts.[1] The fact is that reasoned knowledge is never looked upon as the finally efficacious means of determining the real, and this sceptical attitude towards the efficiency of reason is all the more striking in a system which addresses itself to the task of discovering the morphology of knowledge. Right knowledge which leads to emancipation is not to be acquired through rational philosophising alone, for 'manana' is only one of the stages in the progressive advance to truth.[2] The essential nature of the objects whose knowledge is involved in self-knowledge is, according to the orthodox systems, impervious to the ordinary faculties of knowledge, and so beyond the field of rational explorations. These objects or **प्रमेया** therefore can be rightly known only through an extraordinary faculty of immediate intuition, though for this it may be necessary to reason about them as a preliminary measure of self-discipline. Nyaya limits its function to the exposition of right 'manana' leaving it to other shastras to point out the further method of intuition or **तत्त्वसाक्षात्कार.**

Intuition in Vedanta.

When we come to the Monistic speculations of India, the superior claims of intuition become much more outstanding and impressive. The Vedantic writers do not content themselves with subordinating the function of reason to a supra-rational faculty as is the case with the Naiyayikas. On the contrary, they are often ready to accept the extreme

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[1] **तत्त्वाध्यवसायसंरक्षणार्थं जल्पवितण्डे बीजप्ररोहसंरक्षणार्थः कण्टकशाखावरणवत्** *Nyaya Sutra* 4. 2. 50.

[2] For more explicit statements on the limits of reason within the Nyaya System we may turn to the fourth chapter, where Gotama openly insists on the need of a further discipline in the shape of Yogic practices, and of all the rules and observances that are subsidiary to Yoga. Prof. Max Muller rightly complains that this is a very humble view to take with regard to a system of philosophy which at the very outset promised final beautitude. To what extent a Naiyayika may be convinced of the value of immediate intuition may be gathered from Udayana's

position of unqualified irrationalism by emphasising the opposition of intuitional deliverances to the testimonies of sense and reason. Thus, e.g., Shankara, almost in the strain of the Latin Fathers of the Middle Ages, ascribes the inadequacy of all empirical knowledge ultimately to the innate Ignorance which is at the root of all evils. All the secular canons of knowledge, are limited to the province of Ignorance, because, we are told, "without the delusion that I and mine consist in the body, sense-organs, and the like, no knower can exist, and consequently a use of the means of knowledge is not possible." Such a sweeping remark on the part of a philosopher on the inadequacy and perversity of the ordinary means of knowledge will surely strike as altogether extraordinary to those who would like to reject the so-called higher faculty as an extra-philosophical criterion. Yet, Shankaracharya, who is widely accepted as the most gifted of the Vedantic thinkers, is perhaps also the most emphatic in distinguishing between the *apara vidya* and the *para vidya*, and in tracing our cognitive perversity to an innate cause. Now what is important for our present purpose is that Vedantism, more than any other Indian system, is characterised by a very persistent effort to stake its epistemological prestige on a type of extraordinary experience which is so opposed to our ordinary experiences that neither sense nor reason is supposed to reproduce its contents. This specific type of experience is believed to be indispensable for the attainment of the *summum bonum* inasmuch it alone reveals the substantial identity of the individual self with the universal substratum. The fact of this identity being unrealizable through the ordinary means of knowledge which produce the fiction of difference, truth is unattainable except through that intuitive ex-

account of the origin of the different systems from the different types of intuitional excellence—See the concluding portion of the *Atmatattvavivela*.

perience. Until this experience is realized and actually lived, the individual has necessarily to rely on the unquestionable authority of the Holy Writ. Hence again Shankara insists that out of the *pramanas* which are useful for *apara vidya, sabda* is the only reliable guide.[1] The paramount importance of intuition for the knowledge of the Real receives unqualified emphasis when it is urged that even the Scripture is not the final means of knowledge, but scriptural texts on the one hand, and intuition on the other hand, are to be depended on.[2] This intuition is then the ultimate criterion, of which reasoning even when it is supported by the sacred texts is a subordinate auxiliary.[3]

Intuition in Yoga

For a fuller justification of this Vedantic evaluation of the different sources of knowledge and the subordination of all the ordinarily accepted means of true belief to an extraordinary immediate intuition, we must turn to the Yoga analysis of knowledge which, as suggested above, furnishes the underlying basis of the different epistemological theories of India. True knowledge, according to the Patanjal views. is not a matter of mere speculation. On the contrary, our theoretical endeavours are without exception vitiated by the inevitable presence of factors which obstruct the immediate vision of truth. Owing to the intimate association which ordinarily exists between the name and the meaning, and the necessity thence arising of thinking with the help of language, we always run the risk of mistaking the forms of language for the forms of thought. This mistake leads to a number

[1] वदेस्य हि निरपेक्षं स्वार्थे प्रामाण्यं रवेरिव रूपविषये Shankara's Com. II, 1. 1. On the other haud स्वभावतो विषयविषयाणीन्द्रियाणि न ब्रह्मविषयाणि Com. I. 1. 2.

[2] न धर्मजिज्ञासायामिव श्रुत्यादय एव प्रमाणं, ब्रह्मजिज्ञासायाम् । किंतु श्रुत्यादयोऽनुभवादयश्च यथासंभवमिह प्रमाणं अनुभवावसानत्वाद्भूत वस्तुविषयत्वाच्च ब्रह्मज्ञानस्य Com. to I. 1. 2. Cp. also II. 1.4.

[3] श्रुत्यनुगृहीत एव ह्यत्र तर्कोऽनुभवाङ्गत्वेनाश्रियते Com. to II. 1. 6.

of false beliefs about reality. Every form of language is supposed to have a corresponding form of existence[1], and this even where there is no such correspondence at all in reality. For a seeker after truth, then, it is absolutely necessary to destroy the associative links between the meaning or object of knowledge, and the names which are meant for their expression.[2] Apart from the विकल्पवृत्ति which has its source in language, there is another distorting agency in our ordinary methods of acquiring knowledge, namely, the 'I think.'[3] Hence the highest type of experience is not only conditioned by शब्दसंकेतस्मृति परिशुद्धि, but is also characterised by the complete absence of self-consciousness. It is called perception *par excellence* inasmuch as through this alone is revealed the real nature of the object. Here we come upon the real secret of that implicit faith in the Holy Writ which is a general feature of the orthodox systems. The supreme authority which is claimed for the Vedic lore and the reverential awe with which the toughest intellect hastens to accommodate his epistemological findings to Revelation arise out of a preconceived ideal of knowledge, though in some cases it assumes the appearance of a blind faith in authority. Right knowledge then, as it is conceived by Indian orthodoxy, should be acquired through other than the ordinary methods, and transmitted through other than the ordinary means of communication. Hence again the need for a right preceptor who having realised

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[1] वस्तु शून्यत्वेपि शब्दज्ञान माहात्म्यनिबन्धनो व्यवहारः—*Yoga Bhasya* on the Sutra 9.

[2] This destruction of the bonds of association or स्मृतिपरिशुद्धि is likely to be undervalued by those who insist on the intimate and useful relation between thought and language. Yet, however, this association has been as often extolled as regretted by many a thinker of the west too.

[3] This too must strike many as something monstrous, implying as it does the denial of the most fundamental transcendental condition of experience.

the truth by means of an immediate intuition—hence called तत्त्वदर्शी— can also dispense with the help of language in transmitting it to his desciples. The more frequent method of transmission however, is to have recourse to the ordinary medium of language, and so the intuited content comes into contact with that self-same distracter which stood between the subject and the object. Hence again the necessity of *shravan*, *manan* and *nididhyasan*.

VEDANTA AND YOGA

It appears to be pretty clear in the light of the above considerations that a faculty altogether different from the ordinary ones was unanimously considered to be the supreme organ of knowledge. This was not only true of the so-called logicians who avowedly believed in the potency of rational discussion for yielding right knowledge; it was equally true of the monists who apparently thought it necessary to undertake a rational refutation of the Yoga philosophy. It is true that the Yoga philosophy does not meet a better fate than the other systems at the hands of the monistic thinkers, and Shankara in particular appears to be uncompromising in his polemics against the Yoga method of realization.[1] But to interpret this as tantamount to an unqualified denial of the efficiency of intuitional experiences is to miss the real source of strength in these speculations. On the contrary, it is only on the ground of a specific type of experience which is supposed to give us a direct perception of Reality, that Shankara rejects those methods that lead to other types of experiences. That is, it is first of all assumed by Shankara that the Real is revealed only in that type of experience in which the experient actually feels

[1] न सांख्यज्ञानेन वेदनिरपेक्षेण योगमार्गेण वा, II.1.3

his identity with the cosmic consciousness, and then on the strength of this assumption he rejects the epistemological claims of those methods and experiences which contradict the method and the deliverances of that specific experience. Even the Shrutis are so interpreted—interpretation which are bound to appear to an impartial reader as forced and far-fetched on critical points—as to conform entirely to the contents of that experience, and then the rival systems are shown to have misunderstood the Sacred Writ. Whether that experience is called mystic intuition or not is a matter of words only.[1] But the fact remains that the experience which is made the basis of Vedantic metaphysics is something so unique and opposed to the ordinary methods of knowledge, that the Vedantin should have no quarrel with the other orthodox philosophers in considering speculative philosophy as a mere auxiliary, incompetent by itself to reveal the Real. This in fact is clearly suggested by Vachaspati Misra when he hastens to add that the Vedanta Sutra, एतेन योगः प्रत्युक्तः, does not deny the evidential authority of the Yogic philosophy.[2] And Shankara himself not only acknowledges the authority of those portions of Yoga which do not differ from his own monistic metaphysics, but he openly declares that the Self which is unevolved and entirely free from all plurality is seen by the Yogi.[3] So, it has been justly point-

[1] Yet this has furnished a topic of controversy, some thinking that Shankara "himself would be the last to acknowledge, and build his system upon, mystic vision as the main source and criterioin of truth and motive of certitude," Professor Zimmermann's article in *Indian Philosophical Review*, Vol. II, No. 4.

[2] नानेन योगशास्त्रस्य हैरण्यगर्भपातञ्जलादेः सर्वथा प्रामाण्यं निराक्रियते, किन्तु जगदुपादानस्वतन्त्रप्रधानतद्विकार—महदहङ्कारपञ्चतन्मात्रगोचरं प्रामाण्यं नास्तीत्युच्यते। न चैतावतैषामप्रामाण्यंभवितुमर्हति *Bhamati*.

[3] एनमात्मानं निरस्तसमस्तप्रपञ्चमव्यक्तं संराधनकाले पश्यन्ति योगिनः —Commentary on the Sutra, III, 2. 24. Indeed the acceptance of yogic intuition by Shankara is strongly suggested by innumerable passages of his commentaries on the Upanishads, the Sutras, and the Bhagvat Gita. The Vedantists have

ed out[1] that here the ultimate "warrant of authority is actual experience which is not a specific form of proof co-ordinate with other forms but the basis of all these—the Self itself of a supra-sensible kind. . . . If then the Vedanta affirms that notwithstanding apparent plurality all is one . . . it is not merely because argument leads to a Monistic conclusion . . . but because that unity has actually and really been experienced directly by those who affirm it . . . the Vedanta is not a mere system of philosophy in the modern western sense. It is based on Revelation. If not so based, it is worth no more and may be worth less than any other particular philosophy."

The Organ of Philosophy.

The conclusion then appears to be inevitable that the real strength of the orthodox systems of philosophy in general and that of Vedantism in particular lies in certain types of intuitional experiences which furnish the actual foundation of knowledge and belief. And here we come upon the most deep-lying contrast between Indian philosophy and that aspect of western speculations which, inaugurated by the anti-scholastic respect for reason as

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not only accepted the validity and usefulness of the *Samadhis* called *Savikalpa* and *Nirvikalpa* in general, but Patanjali's account and classification of *Samadhi* have been sometimes accepted without qualification. Shankara, however, is generally believed to have underrated the yogic practices in so far as these are not recognised as sufficient by themselves to lead to the development of the identity consciousness. Thus, Madhusudan Saraswati says regarding Shankara and his school that श्रीभगवत्पूज्यपादाः कुत्रापि ब्रह्मविदां योगापेक्षां न व्युत्पादयाम्बभूवुः, अतएव चौपनिषदाः परमहंसाः श्रौते वेदान्तवाक्यविचार एव गुरुमुपसृत्य प्रवर्तन्ते ब्रह्मसाक्षात्काराय, न तु योगे, विचारेणैव चित्तदोषनिराकरणेन तस्यान्यथासिद्धत्वात् ।——Commentary to Gita, VI, 29. Shankara's however, says explicitly that योगस्य यत्फलं ब्रह्मैकत्वदर्शनं । But whatever may be the meaning of yoga for Shankara, there is no denying the fact of his appeal to an extra-ordinary experience as the final authority. The assertion that नोत्पद्यते विना ज्ञानं विचारेणान्यसाधनैः, (अपरोक्षाऽनुभूतिः), emphasises only the peculiar technique by which the identity-consciousness has to be attained.

[1] Sir John Woodroffe, *The World as Power Reality*, p. 108.

the supreme court of appeal in matters of knowledge, crystallized into the epistemological doctrines of Kant, Hegel and all other subsequent philosophers of the west. Judged from this standpoint, we must candidly admit that the appeal to the Vedas does involve a reference to an extra-philosophical standard. Of course, every man is free to define philosophy in his own way, and we should not be denied the right of so conceiving philosophy as to place intuitional experiences in the very centre of our metaphysical adventures. But then we must be careful not to impair the centrality of these experiences by the desire to find for them a place in a rational scheme of the universe. It is no doubt true that the intuitional experiences are after all experiences and not mere figments of imagination, but to urge that these experiences should be taken into account in "any rational rendering of reality" is, we venture to think, nothing short of a serious confusion of issues. Intuition founded on the impotency of Reason cannot conceivably enrich itself by submitting to a rational interpretation. No subterfuge of language therefore should be allowed to obliterate the methodological contrast between Indian absolutism and the monistic philosophy of modern Europe, particularly that of Hegel. To put this contrast in a clear light we may just consider the strong conviction with which Dr. E. Caird says that "the claim of special inspiration is an anachronism for the modern spirit which demands that the saint should also be a man of the world, and that the prophet should show the logical necessity of his vision. For 'a man's a man for a' that,' and however sensuous and rude his consciousness of himself and of the world may be, it is, after all, a rational consciousness, and it claims the royal right of reason to have its errors disproved out of itself. And a philosophy which does not find sufficient premises to prove itself in the intelligence of every one, and which is

forced to have recourse to mere *ex cathedra* assertion, is confessing its impotence.''[1] Hegel's attitude to the mystical method is well-known. His invectives against immediate feeling as the organ of philosophy and his insistence on the need for mediation are too clearly stated[2] to leave room for confusion between the intuitional method and the philosophical method of Hegel.

Are the *panchakosas* categories?

Yet, however, such confusions are not altogether wanting in the writings of the most gifted modern contemporary exponents of Indian thought. The Vedanta thinkers are supposed to have sometimes approached the problems of philosophy from the standpoint of the dialectical method of Hegel.[3] In the Taittiriya Upanishad, it is said, "we find expressed the central contention of the idealist that in all systems of philosophy there are elements of truth as well as inherent defects, limitations which lead us on to some other more concrete development which, again, has to be transcended. . . . . . By an immanent criticism of conceptions, we are enabled to discover the most complete or the most fundamental idea, relatively to the rest.''[4] "We start with a lower category, criticise it, discard it as incomplete and progress to a higher one wherein the lower receives its fulfilment." That is, the Taittiriya Upanishad, far from being fanciful in its notions as judged by Dr. Weber, exhibits the true spirit of speculation in so far as it illustrates the method of the "progressive discovery of reality or defining of reality in terms of fundamental conceptions or categories, or a gradual passage from lower, more abstract and indefinite conceptions, to higher, more concrete and definite ones." This

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[1] *Hegel*, p. 131.

[2] *E.g.*, in the Preface to the *Phenomenology*.

[3] Professor Radhakrishnan, *Indian Philosophy*, p. 164.

[4] *The Reign of Religion in Contemporary Philosophy*, p. 413.

method, it is hardly necessary to remark, is the full-fledged dialectical method of Hegel. Now the question is whether such an interpretation of the dialogue between Varuna and Bhrigue is justifiable or not. That the Upanishads are not very distinguished for their intellectualism, and that their logical basis is almost insignificant are almost unanimously accepted by the Indian as well as the western orientalists. "There is not to be found in them," says Prof. S. N. Das Gupta, "any pedantry or gymnastics of logic,"[1] and their discussions "by themselves are hardly logically convincing, having not unoften an almost infantine naiveté about them."[2] Now even if it be granted for argument's sake that such sweeping remarks on the philosophical basis of the Upanishads are fundamentally untrue, arising from a partial view only, the dialectical method of Hegel and the Upanishadic dialogue do not appear to have a single point of contact with each other when they are judged on their own merits. It will perhaps be readily admitted that the generally accepted interpretation of the dialogue has very little in common with the immanent criticism of categories which for Hegel reveals the Absolute. The method of explaining the Absolute, as it is suggested in the Upanishads, is to begin with most easily apprehensible thing and then to lead the seeker after Truth through a series of progressively subtle things to the knowledge of the Absolute which is supposed to be the most difficult of comprehension. This method of gradual transition from the grossest to the subtlest is more than once illustrated in the Upanishads, and the terms of the series are not generally repeated. Thus, apart from the numerous ineffectual attempts at defining the Absolute which are found throughout the

[1] Prof. Das Gupta, *History of Indian Philosophy*, p. 43.

[2] Prof. Krishna Chandra Bhattacharya, *Studies in Vedantism*, p. vii.

Upanishads, the teacher often leads the student upwards from the conditioned to the conditioning, from the subtle to the subtler. The case of Bhrigue in the Taittiriya Upanishad, for example, is the same as that of Narada in the Chhandyogya Upanishad; and in explanation of this method it is said that like the mounting of a staircase, the exposition proceeds from the gross to the subtle and subtler truths.[1] These explanatory things then are meant for drawing our attention to what actually lies beyond them, or rather, what is the essential Reality of which these are mere appearances. By negating the whole lot, the student is directed towards the positive basis of all negations. The Absolute is what remains over when all the sheaths or kosas are negated.[2] This interpretation, it is hardly necessary to repeat, does not evidently bear any resemblance to Hegel's method. It rather points to the opposite direction.

Further, the attempt to dove-tail the Hegelian method on the Vedantic theory of Kosas is not simply to deprive Indian philosophy of its peculiar psychology, and metaphysics. It further leads to all the disadvantages of ignoring the historical lineaments of philosophical problems. Hegel's method of discovering Reality by an immanent criticism of our categories has an intellectual background so entirely unlike anything that existed in India and the presuppositions of these two types of philosophy are so different that nothing of permanent

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[1] सोपानारोहणवत् स्थूलादारभ्य सूक्ष्मं सूक्ष्मतरञ्च बुद्धिविषयं ज्ञापयित्वा तदतिरिक्तस्वाराज्येऽभिषेक्ष्यामीति नामादीनि निर्दिदिक्षति Shankara's Com. on Chh. VII, 1. It has been remarked that "it is impossible, in spite of the rich poetic ornament with which these ideas are set forth, to discern a satisfactory reason for this progressive advance." Prof. Paul Deussen, *The Upanishads*, p. 93.

[2] Cf. अपनीतेषु मूर्त्तेषु ह्यमूर्त्तं शिष्यते वियत्। शक्येषु वाधितेष्वन्ते शिष्यते यदेवतत्। Vidyaranya Muni, *Panchadashi*, IV.

philosophical interest can result from reading one into the other. The theory of categories, as is well-known, developed out of Kant's attempt to reconcile the conflicting claims of empiricism and rationalism about the origin of knowledge. The function of thought and that of sense in the constitution of knowledge were entirely separated from each other by the previous thinkers, and hence arose the necessity of a fresh analysis of perception in order to determine the rôle thought plays in perception in particular and knowledge in general. This analysis led to the all-important discovery that the ultimate forms of thought and the forms of existence are identical, so that it is possible to know the ultimate determinations of reality through an adequate analysis of reason. This identification of the intellectual necessity with the metaphysical which is strongly suggested by the Kantian analysis of knowledge could not be completely realized by Kant owing to his faith in something beyond the field of intellectual exploration. Hence the immediate duty of his successors was to adhere consistently to the central epistemological principles of the Critique by removing from it all the useless excrescences which had no organic relation with the main purpose of the transcendental enquiry. Thus Reason, in the hands of Hegel in particular, establishes its unqualified supremacy and the region of the Unknowable is once for all blotted out of existence.

It would be useless to repeat these platitudes about the philosophy of Kant and Hegel, had it not been necessary in studying philosophical problems to realize that notwithstanding the unity of the intellectual movements of different people, there are very significant differences too that are reflected not only in the special problems but also in the special methods employed for their solution. The theory of categories and the method of immanent criticism, we venture to think, are such specialities. With regard

to the Hegelian dialectic, it has been remarked[1] that "it is not the only object of the dialectic to prove that the lower and subordinate categories are unable to explain all parts of experience without resorting to the higher categories, and finally to the Absolute Idea. It undertakes also to show that the lower categories are inadequate, when considered with sufficient intelligence and persistence, to explain any part of the world. . . . The whole chain of categories is implied in any and every phenomenon." It is further pointed out that "since we cannot observe pure thought at all, except in experience, it is clear that it is only in experience that we can observe the change from the less to the more adequate form which thought undergoes in the dialectic process. But this change of form is due to the nature of thought alone, and not to the other element in experience—the matter of intuition."[2] It is evident from these characteristics of the Hegelian dialectic, how intimately it was connected with the contemporary distinction of pure thought from mere sense, of experience from reason, and finally of the immanent criticism of one category by another from the criticism *ab extra* of thought as such. The strong repugnance which Hegel had to all forms of transcendent criticism of thought was evident from his inability to accept even the "intellectual intuition" of Schelling. If the philosopher, to quote Dr. E. Caird once more,[3] "assumes propretic airs, or speaks to ordinary men from the height of 'an immediate insight' or 'transcendental intuition,' from which they are excluded—he, as Hegel soon began to assert, is pretending 'to be of a different species from other men,' and is 'trampling the roots of humanity under foot.' The contrast between the dialectical method and the intuitional

[1] Dr. McTaggart, *Studies in the Hegelian Dialectic*, p. 19.
[2] *Ibid.*, p. 18.
[3] *Hegel*, p. 57.

method cannot conceivably be presented in a stronger form. There was not only no occasion in Indian philosophy to distinguish between the form and the matter of experience which gave rise to the Hegelian method, but the latter was developed in direct antagonism to what was accepted in India as the only right method of approaching Reality.

Did Vedanta anticipate Kant's distinction between concept and percept?

With regard to the first point, however, it may be asked if the Vedanta thinkers did not hold that "true insight is born of the union of the universal and the particular," and thus anticipated long ago what Kant discovered only in the eighteenth century, namely, that "percepts without concepts are blind; concepts without percepts are empty."[1] Similarly, regarding the second point, it may be urged that "Intuition does not cease to be rational simply because reason is transcended. Intuition is the crown of reason."[2] To begin with the latter point, though the belief that there is no necessary antagonism between intuition and reason has found favour with many a modern exponent of Indian thought, none has as yet been able to justify this belief. "The intuitional," it is urged,[3] "is not contradictory of the logical, but subsumptive of it." It is however candidly acknowledged that we cannot form the remotest conception of the ways in which the palpably contradictory attributes are referred to the Upanishadic Absolute.[4] Now even if it be granted that the belief is justifiable, and this is not our present contention,[5] it does not affect the contrast of the Hegelian method

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[1] Prof. Radhakrishnan, *Contemporary Philosophy*, p. 423.

[2] *Ibid.*, p. 438.

[3] *E.g.*, by Prof. R. D. Ranade, *Upanishadic Philosophy*, p. 6.

[4] Cf. *Ibid.*, p. 347.

[5] Prof. Radhakrishnan however admits that the weakness of the Upanishads "lies in this that the synthesis is reached not by explicit reason but by intuition. (*Indian Philosophy*, p. 264.) It is not easy to see how this admission can be roconciled with the acknowledged superiority of intuition to reason.

with the intuitional. Hegel, we must observe at the risk of repetition, would be the last to subordinate reason to anything external to it; and however imperfect our knowledge of reality may be, he would never think of supplementing the deficiencies of reasoned knowledge by an appeal to a different faculty. Our knowledge as actually achieved may fall far short of our ideal of what it ought to be, and perhaps the ideal will not be completely realised while man is man, as Green would suggest. But with all these admissions, Hegel would surely urge that "All true philosophy must be mystical, *not indeed in its methods*, but in its final conclusions."[1] If we now turn to the first point about the analogy between Kant and the Vedanta thinkers, our conclusion will be the same. Notwithstanding a few fundamental points of contact between the Vedantic teachings and the results of the Critique, their methods are poles apart. By that admirably pithy expression regarding the relation of percept to concept Kant, as is known too well to need elucidation, meant to emphasise the functions of both thought and sense in knowledge. Knowledge for him is objective only in so far as the immediately given sense-data are brought under the interpretative activity of thought. Now, as already urged, such a distinction of sense and thought requires far other types of intellectual atmosphere to foster in than what could exist in India. In view of the complete absence of any reference to this distinction between thought and immediate experience in the philosophical records of India, it would be surely fanciful to foist the Kantian expression in the Upanishads. The fact is that the affiliation of the

[1] McTaggart, *Hegelian Dialectic*, p. 255. Italics not in the original. It has been sometimes claimed that mysticism is not occultism and that it is a perfectly intelligible mode of God-realization (compare, *e.g.*, Mr. Underhill, ***Mysticism***, p. x). But this is not the point at which Hegel joins issue with mysticism. His real polemic is directed against its purely immediate unity, as is evident from his criticism of the unmittelbares Wissen of Jacobi.

Kantian and the Hegelian thought to Vedantism has been made possible through putting extremely far-fetched interpretations upon the terms *manas*, *Vijnana*, etc., as they occur in the monistic speculations of India. It is not at all easy to see the extent to which such terms as *manas* and *Vijnana* have to be twisted before they can connote perception and understanding respectively, as they occur in the philosophical literature of the west. Our failure to see this may be due to our short-sightedness, but we must emphatically maintain that these interpretations are entirely fanciful and unwarranted. Apart from this, such misinterpretations have the disastrous result of obscuring one of the unique characters of Indian thought. It has been contended above that intuitional visions play a very important part in Indian epistemology. They are intimately connected with the Vedantic theory of knowledge in particular, which includes among other things meditation or contemplation. That immediate experience of Identity which is supposed to be the only true experience is but the last result of concentration and is preceded by other types of experience.[1] Thus Bhagavat Gita describes the intuitionist *par excellence*[2] as he who meditates upon God. Intuitional experiences are chiefly distinguished according as they lead to the perception of God or that of Self. Out of these two types, the latter is the final result of previous concentrations on the five sheaths or kosas one after another. It is true that these are recognised as aids to the knowledge of the Absolute; but their importance does not consist in their being categories or thought-forms. On the contrary they are objects of concentration of different degrees of intensity and thus useful for the control of the external and the internal senses.

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[1] Cf. नामादीनि ब्रह्मत्वेनोपास्य तत्फलञ्च भुक्त्वा क्रमेणाप्याद्ब्रह्मभावं प्राप्नोति Ananda Giri's *Commentary on Shankara Bhasya.*

[2] *Gita*, VI, 47.

Shankara explicitly ascribes these five sheaths to Ignorance,[1] and as the Absolute appears identical with these five outer cells, their discrimination results in the consciousness of identity between the subject and the ground of cosmic existence. Indeed, to interpret these cells as so many categories which by an immanent dialectic reveal the Absolute is to throw overboard the peculiarities of the Vedantic psychology.

Conclusion.

We conclude then that the Hegelian method of knowing the Absolute by an immanent criticism of categories is different and in some respects altogether opposed to, the Vedantic method of right knowledge. For the Vedantist, the ultimate criterion of truth is an immediate experience; the function of thought or reason in the western sense is either not recognised at all;[2] and even when it is used in the approximately western sense, it is made subordinate to immediate experience. For the Hegelian, on the contrary, no experience in its immediacy can furnish the ultimate criterion and claim the exclusive right to reveal the Real; for, it is revealed only in so far as the mediating activity of thought has been allowed to operate upon the multitudinous varieties of experience. According to Vedantism, the falsity of an immediate experience " is not to be judged *a priori* "[3]; for Hegel, an experience is to be judged false precisely in the same degree in which it fails to satisfy the *a priori* ideal of a coherent system.

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[1] अविद्याकृत पञ्चकोशापनयनेनानेकतुषकोद्रववितुषीकरणेनेव तण्डुलान् प्रस्तौति । *Com. to Taît, Up., Br. Valli, II.*

[2] *I.e.* Reason as the source of the fundamental principles on which our thinking and action depend was never recognised in India where the contradictions in the rationally reached conclusions led to the condemnation of the thinking process in general. This has been called the " Superficial Doubt," as distinct from criticism. —See Caird's *Critical Philosophy*, p. 4.

[3] Prof. Krishna Chandra Bhattacharya, *Studies in Vedantism*, Introduction.

THE ABSOLUTE OF ABSTRACT PANTHEISM

Scotus Erigena and Spinoza on the Absolute.

We have so far considered the problem of methodology and attempted to bring out the apparently irreconcilable contrast which Indian absolutism presents in this respect to Hegelianism. As we pass to the consideration of the nature of the Reality as it is conceived in the east and the west, this opposition again confronts us almost in an unmitigated form. And here too we may begin with western scholasticism, with which the Vedantic method has been shown to possess fundamental affinities. Philosophy in the opinion of Scotus Erigena, the founder of the Christian School, is the science of the faith and its function is the understanding of dogma. God who is immanent in the cosmos, is the sum-total of being without division, or limit. He is being without any determination, and being superior to all contrasts cannot be adequately described in language. But though God is incomprehensible through human categories, and hence is the absolute nothing for our thought, yet it is not equal to O. On the contrary, it is the positive ground from which the world is derived. Equally impenetrable is the innermost essence of the human soul which is identical with God. It is hardly necessary to point out that these thoughts of Erigena are so similar to those of Vedanta particularly of the Shankarite School, that they can be easily taken to be a short résumé of the Vedantic metaphysics. Now, the main difficulty in such a metaphysics is that of describing the indescript. With its absolute sundering of the 'what' from the 'that,' it takes away the possibility of distinguishing between being and nothing; for that which is supposed to repel all predication and essentially unthinkable on this account dwindles into nothing. Erigena's device to overcome this difficulty, like that of the mystics in general, is to resort to

the *vision* or immediate knowledge of God. Outside the scholastic attempts which sometimes reach the climax of intellectual nicety, it is in the works of Spinoza that we find a most serious tussle with this fundamental problem of pantheism. The problem is to ascertain how the *ens absolute indeterminatum* is related to the attributes. Spinoza appears to have left this relation sufficiently ambiguous to admit of two opposite interpretations, called formalistic and realistic respectively. According to the former view which has the authority of Hegel, the attributes are merely *in intellectu*, and so do not qualify the substance. It is merely from the view-point of thought or understanding—which can conceive of anything only by attaching predicates to it and for which consequently that which cannot be made the subject of significant judgments is absolutely nothing—that the indeterminate substance, existence in itself, or pure being, is changed into attributes. That is, Pure Being in itself is completely destitute of all determinations, and the attributes are what intellect 'perceives' concerning it, as constituting the essence thereof. If this interpretation of Spinoza's thought be correct then the recognition of limitations of our intellectual faculty or reason appears to be a fundamental feature of his pantheism. Coming now to Indian philosophy a strikingly similar line of thought in connexion with the self-same problem is illustrated in the schools of Vedanta. The school of Shankara represents Spinozism as interpreted in accordance with the formalistic view, while the realistic aspect is represented by Ramanuja and his followers.

THE BRAHMAN

Shankara's Absolute, like Erigena's God or the Substance of Spinoza, is explicitly described as Pure

Being, altogether free from determinations and exclusive of difference. Distinctions, he points out, may be of three types only; namely, the difference of a thing from its parts, that of one species from another under the same genus, and finally that of one thing from another of a heterogenous type. The pure identity of the Absolute is entirely free from these three possible kinds of difference. Indeed the unique nature of Shankara's monism which distinguishes it from all other types of Indian thought consists just in this uncompromising insistence on the purely indeterminate analytic unity of the Absolute. That this unqualified monism is Shankara's metaphysical position becomes obvious not only from what he himself teaches in the different parts of his commentaries; it is equally clear from the strictures it has received at the hands of the critics of different schools of thought as well as from the subsequent history of Vedantic thought in the school of Shankara. A system which takes the featureless analytic unity to be the foundational principle of the universe must necessarily stake its speculative excellence on the success with which it can reconcile the apparent plurality of the immediately given world of experience with the metaphysical pure unity of the cosmic principle. Apart from this central crux in all varieties of pantheism, Shankara has to tussle with the further problem of the emergence of qualities or attributes out of the perfectly indeterminate pure Existence. His answer to the first problem has much in common with that of Parmenides and Plato. Having rejected evolution or *parinambada* as implying potential plurality in and hence inconsistent with, the pure identity of the Absolute, his only alternative is to condemn all plurality as mere illusion or unsubstantial appearance. But the more the phenomenal world is condemned as a mere illusory appearance, the more pressing becomes the need of accounting for the existence of this illusion. For,

a fact in order to be denied or judged false must at least exist, and till this existence of the Unreal is reconciled with that of the Real, we are left in a hopelessly dualistic metaphysics. Hence the phenomenal world is a great source of trouble to Plato, Parmenides and Shankara alike. Outside the Idea, Plato urges at every step, there is nothing but non-being; outside the Brahman, says Shankara, there is nothing but Avidya which does not really exist. But in the very act of denial, the Non-being or the Avidya comes to possess a positive significance, and the critics of Plato as well as those of Shankara have demanded an explanation of this apparently second constitutive element, this non-being which, for the Greek as well as the Indian thinker, is the source of all plurality and evils. The Avidya has an eternity *ab ante;* how can this second principle which is co-eternal with the Absolute be reconciled with the sole reality of the One? This reconciliation in the opinion of many critics of Plato and Shankara is impossible; and so Shankara's analogy of the magician has failed to silence the critics who find in Maya a second principle that 'refuses to be reduced completely to the unity of Brahman.' Absolute monism, it is urged by Jayanta Bhatta, cannot dispense with a second principle, and the admission of another eternal principle alongside Brahman is fatal to a monistic metaphysics.[1] This dilemma, indeed, is inevitable in some form or other in every type of monism. The illusion of Parmenides, the non-being of Plato, the Maya of Shankara, the matter of Plotinus, and even the negativity of Hegel and the matter

[1] केयमविद्या नाम । ब्रह्मणो व्यतिरिक्ता चेन्नाद्वैतमव्यतिरेके तु ब्रह्मैव सा, *Nyayamanjari*, IX, 526. Again, अविद्यायामसत्यां सर्व एवायं यथोदाहृतो व्यवहारप्रकारस्तत्कृत इति नावतिष्ठते, सत्यां तु तस्यां नाद्वैतमिति । *Ibid*, p. 531, Gangadhar Shastri's edition, Part II. Shankara's only reply is that the difference between the Brahman and the Avidya is false, because it does not exist at a particular stage of illumination—See *e.g.*, *Brih. Upanishad*, III. 5.

of Bergson stand out as dualistic excrescences disfiguring the monistic purity of their systems.

MAYA

Shankara's own device here is to fall back on metaphors which have opened the way to endless controversy within as well as without his own school. It is by no means an easy task to extricate a consistent notion of Maya from the apparently conflicting accounts of it given by different monists, who differ from each other widely on a number of relevant problems of vital importance. Maya is described by Shankara as consisting of name and form or नामरूपात्मिका and not determinable either by being or by non-being तत्त्वान्यत्वाभ्यामनिर्वचनीया ; and the Absolute is Pure Being which by reason of its purity is mistaken as non-being. Prior to the creation of the universe there was mere Being.[1] This, as Shankara is careful to point out, does not signify a subsequent distortion of the genuinely Real. Even now it is Pure Being but differentiated into names and forms, quite as much as the magician is never distorted by the magical show of his own making.[2] Yet, when pressed for a definite answer to the relation between the Absolute and the Maya, he has to admit that the undistorted Brahman transforms itself into the transmigrating individual soul by means of its own *avidya*, and frees itself from this bondage by its own *vidya*.' A similar difficulty attends the second characterisation of Maya as neither being nor non-being. As contrasted with Brahman which is pure existence, Maya is non-existent, but as the ground of the phenomenal world of experience it is not mere non-being. In this connexion, it is sometimes pointed out that the non-being of Maya is not absolute. Though

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[1] सदेव सोम्येदमग्र आसीदेकमेवाद्वितीयम्—*Chh. Up.* VI. 2.

[2] यथा स्वयं प्रसारितया मायया मायावी त्रिष्वपि कालेषु न संस्पृश्यते अवस्तुत्वात् एवं परमात्मापि संसारमायया न संस्पृश्यत इति—*S. Bhasya*, II. 1. 9. Cf. also *Brih. Upanishad, III. 5.*

eternal *ab ante*, it is completely annihilated at the dawn of right knowledge; but Brahman is truly existent for it never ceases to be. So, if pure being or genuine existence consists in eternal being as is apparent from the technical definition of सत्यत्वं as बाधराहित्यं, then such a genuine reality cannot belong to Maya. Here too the pressure of logic has sometimes driven Shankara to the apparently conflicting admission that Maya is not only unreal in the sense of the transient, but it is absolutely unsubstantial and literally false or अलीक like the son of a barren woman.[1] The Vedantic contrivance for reconciling these conflicts by means of the usual distinction between the esoteric and exoteric knowledge is well-known. But without considering the significance of this distinction and the right of introducing two heterogeneous standards of truth into a system of philosophy, it may help to clear up the issues to make a short reference to the second problem mentioned above, namely, the emergence of qualities out of the absolute indeterminateness of pure being.

Shankara, as suggested above, has to encounter here the same difficulties as Spinoza. How can that which is essentially an *ens absolute indeterminatum* be also described as possessed of determinations? Shankara, as is well-known, not only distinguishes between the higher and the lower Brahman, but he also proceeds to characterise the former as *satyam*, *jnanam*, *anantam*,[2] and thus makes himself liable to attack alike from the theistic monists and the logicians. That which is purely indeterminate, it is urged by the critics, can never be the object of knowledge.[3] Hence those portions of the Sruti which have explicit

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This is rightly pointed out by Prof. Das Gupta (*History of Indian Philosophy*, p. 443.) But it is not clear how this view is only "another way of expounding the first view."

[2] *Tait. Upanishad, Br Valli Bhasya* I.

[3] Cf. बुद्ध्यादिभिश्चात्मलिङ्गैर्निरूपाख्यमीश्वरं प्रत्यक्षानुमानागमविषयातीतं कः शक्त उपपादयितुं—*Vatsyayana Bhasya* IV. I. 21.

reference to the indeterminate Brahman are not, it is said, to be interpreted as supporting absolute indeterminateness. They only signify the absence of ordinary qualities from God.[1]

Shankara, however, was not wholly blind to the difficulty of describing the indescript or determining the indeterminate. To qualify, he says in effect, is to limit, and the absolute being all that is does not admit of limitation. But, though indeterminable in this sense, it can yet be defined in the same way as *Akash* is defined as that which gives space.[2] How far it is a genuine solution of the difficulty which has in some form or other been present in every agnostic system has been seriously questioned by the critics of agnosticism in India as well as Europe. The fearless agnosticism of Shankara however does not stop with this distinction between definition and delimitation. The last conceivable step is taken by him when he urges that the Absolute is not only entirely characterless, but not to be grasped through thought and speech. It is unthinkable and unutterable. The word *atman*, it is pointed out,[3] cannot directly signify the indeterminate Absolute; its direct reference is to the determinate Absolute, or Self. But a word may by a sort of indirection refer to something beyond its point of direct reference when the latter is rejected, by a subsequent negation. So the word *atman* directly signifies the self as intimately connected with the super-imposed adjuncts like body. But when these adjuncts are subsequently rejected as not-self, the same word acquires the function of suggesting the pure Ego. This theory of suggestion or *laksana* is evidently indispensable for the unqualified

[1] निर्गुणवादाश्च प्राकृतहेयगुणनिषेधविषयतया व्यवस्थिताः—सर्व्वदर्शन संग्रहः ।

[2] लक्षणार्थप्रधानानि विशेषणानि, न विशेषणप्रधान्येव ।...समानजातीयेभ्य एव निवर्तकानि विशेषणानि विशेषस्य लक्षणान्तु सर्व्वत एव, यथावकाशप्रदाताकाशमिति । *Tait. Upanishad, loc. cit.*

[3] *Chh. Upanishad*, VII, 1. 3.

monism of Samkara's school. It represents the Vedantic attempt to solve the fundamental crux of agnosticism by accentuating the positive significance of negation. Whatever may be the intrinsic worth of the theory, here we appear to approximate the limits of conceptual thinking. And it gives us a clue to understand the Vedantic distinction between the esoteric and the exoteric knowledge.

The abstract identity of pure being, though it is equal to nothing from the standpoint of conceptual thought, is the content of an intuitional experience. In the very act of naming this pure identity we have necessarily to superimpose determinations, and thus make it intelligible and communicable by associating it with what it is not. Hence it is indispensable, for whoever seeks to realize the Pure Being, to think without language and thus have an immediate vision of the Real. The Real in so far as it has to conform to the conditions of conceptual thought must suffer an inevitable distortion and so in place of the Thing-in-itself, we are left with its phenomenal replica or shadow, while the Real reduces itself to a merely problematic concept. Consequently so long as there is the need of communication through the ordinarily recognised channels of spoken or written words the intellectual refraction of the Real will remain at best only symbolic of what cannot conform to the conditions of conceptual knowledge.

Hegel on Pure Being.

If this is a true account of the unqualified monism of the school of Shankara, its opposition to the idealistic metaphysics of Hegel and his followers appears to be unmistakably strong. If there is anything which can be said with absolute certainty about the Hegelian Absolute, it is this that it is not an immediate indeterminate being. It may not be possible for us to know the Absolute in all its determinations, yet it is not essentially indeterminable or un-

knowable. His criticism of Pure Being with which the Logic begins centres round just those elements in it which are so valuable for the intuitionist. He counts this pure being to be the isolation of an abstraction which results from Being and Nothing being placed out of touch with each other. Following the Kantian clue that what is real must conform to the conditions of conceptual thought and the inherent structure of reason, he develops a system of logic which claims to unfold the general structure of the entire universe, and to speak of a thing which is essentially inconceivable is, for him, an indirect admission that it is not within the universe of reality. The mystic and the agnostic may wax eloquent on the indefinability and the unthinkability of the Absolute, and revel in the inscrutable mystery which enshrouds the inner essence of the universe. But the philosopher can ill afford to lay aside the principles of thought and reason, underlying as they do all our assertions, positive and negative; and the validity of which therefore is presupposed in the very act of denying them. Hence the categories or laws of thinking, far from being like blinds which shut out the Real from our vision, are also the characteristics of the Absolute. They are not merely the definitions of the Real from the human standpoint, their function is not to present before us the disfigured picture of the essentially indefinable or a mere refraction of what is essentially beyond the categories. On the contrary, they *are* the Absolute. For him it makes no difference whether we say that the categories are the Absolute or that they are definitions of the Absolute; because, the ordinary conception of knowledge according to which our knowledge has to copy or represent a thing which is outside our mind being a sheer misconception of the nature of knowledge, the question of refraction or disfigurement together with that of correspondence does not arise at all. The indignant protest which the long

line of post-Kantian philosophers beginning with Fichte enter against the Thing-in-itself arises precisely from the distinction which Kant could never get rid of between the world of knowledge and the world of faith, a distinction which is supposed to be entirely inconsistent with the general trend of the transcendental logic. And Kant's sad failure to keep the Thing-in-itself entirely free from the vitiating touch of the categories is generally taken to be an instructive discomfiture for every type of agnosticism. So the common article of faith which binds together the philosophers from Fichte onward into a sort of philosophical fraternity is that the essentially inconceivable is absolutely non-existent, for that which cannot stand as the subject of a significant proposition is a mere naught or void, and so when we indulge in the agnostic's talks about the Real, we only amuse ourselves with empty words. Here we are in sight of an essential agreement between the critics of Shankara and the Hegelians. The theistic Vedantists of the Vaisnavite school and the logicians, as we have seen above, make a common cause against Shankara in rejecting as meaningless a featureless Absolute which by reason of its inconceivability cannot be the object either of perception or of inference and *agama*. Hence the pure Absolute, they point out, is not pure in the sense of being entirely above all determinations. Its purity simply signifies its freedom from the ordinary qualities.[1]

How would a Shankarite reply to these objections? To understand this we must put in a word on the Vedantic psychology of mind. In common with the Samkhya philosophers, the Vedantin distinguishes pure consciousness from *buddhi*

A possible reply to Hegel.

[1] दिव्यकल्याणगुणयोगेन सगुणत्वं प्राकृतहेयगुणरहितत्वेन निर्गुणत्वमिति विषयभेद वर्णनैनेकस्यैवागमाद् ब्रह्मद्वैविध्यं दुर्वचनमिति दिक् ।— Ramanuia, *Vedantatattvasar*.

and its modifications. *Buddhi*, for Samkhya is by itself unconscious and so are its modes. These mental modifications appear to yield knowledge of objects, simply on account of the proximity of *buddhi* to pure consciousness. But the mental modifications being mere changes in *buddhi* cannot by themselves reveal the objects, though they are the indispensable intermediaries through which pure consciousness can come into relation with extra-mental things. Here the only distinction between Samkhya and Vedanta consists in this that the latter, instead of admitting the actual independent existence of *buddhi* as a co-ordinate reality by the side of pure *chit*, looks upon it as a mere adjunct super-imposed on the *chit*. For Samkhya whatever is not *chit* belongs to the unconscious *prakriti* which is a separate principle co-ordinate with *purusha*. For Shankara whatever is an object of knowledge is an unconscious entity which is not only falsely identified with the self, but is also grounded on an unreal principle. Apart from this ontological divergence Shankara agrees with the Samkhya philosophers in his psychological analysis of the functions of the different factors involved in knowledge. The self which is eternal consciousness is the ultimate source of all knowledge; the mental modifications which are involved in the knowledge of objects being themselves revealed by consciousness cannot reveal the subject consciousness. That is, the Pure Ego is never revealed through mental modification or वृत्त्यात्मक ज्ञान inasmuch as it itself is the revealer of all objects. Hence the necessity of knowing the ultimate knower in the state of an extraordinary vision or ecstasy. The series of mental modifications which are necessarily involved in ordinary knowledge must be laid to rest before the self is known as the universal subject and not merely as an object.

However fantastic such an account of Self-consciousness may appear to be,—and it has been called a monstro-

sity [1]—there does not seem to be a less fanciful and more scientific solution of the problem. How is the knowledge of the knower possible?—has been one of the insoluble problems of occidental philosophy since the Kantian criticism of rational psychology.[2] Shankara's solution, whether it is accepted as final or not, does indicate a way out of the difficulty, and incidentally brings out a unique feature of Indian Absolutism. From this standpoint, to know the subject is to be the subject, since the slightest duality is sure to convert the subject into an object, and then in place of the Pure Ego we are left with the empirical self only. Hence the impossibility of knowing the subject through ordinary knowledge which cannot dispense with the duality of subject-object, the subject on the one hand and the presentations on the other. This brings us to the reply which a Shankarite would make to a Hegelian. You cannot grasp, he would say in effect, the Pure Being or the indeterminate Absolute since your analysis of self-consciousness which yields the fundamental principle of unity in difference does not actually solve the problem. Instead of admitting the insolubility of the problem on the basis of your epistemological method, you have simply taken the duality as an inevitable paradox, an *eternal novelty*,[3] or a standing enigma,[4] and then on the basis of this admitted mystery, you discover the Absolute to be an Identity in Difference. As you have pledged yourself to the discovery of the Absolute through conceptual thought, and as the categories which are the indispensable instru-

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[1] *E.g.*, by Prof. Deussen, *The System of the Vedanta*, p. 90, n.

[2] Cf. specially Dr. James Ward's very instructive analysis of Self-consciousness and his conclusion that the subject though within experience cannot be an object of knowledge—*Psychological Principles*, Ch. XV.

[3] Bosanquet, *Contemporary Philosophy*, p. 104.

[4] E. Caird, *Hegel*, p. 149.

ments of such thinking contain identity of opposites, the Reality is distorted in being forced into the conceptual machinery. Indeed, the mystery is mainly due to the necessity of thinking with the help of language; it is this which is responsible for the difficulties which have taxed the intelligence of thinkers in the west since the fourth century B.C. when the puzzle about the Law of Identity was started by Antisthenes the Cynic. Judgments which are recognised to be the units of thought oscillate between abstract identity or tautology and mere difference or pure negation; and the paradox of inference manifests itself in the conclusion going out of yet remaining within the premises. The Pure Identity, then, which is a false abstraction from the standpoint of conceptual knowledge —and it is Hegel's merit to have made it clear for all time —would be perhaps the highest reality if the demands made by the philosophers of India, specially by Shankara and Patanjali had been really met. It is an entirely different question how far those demands can be really met within the range of philosophy, and Hegel at any rate would be the last person to believe in the superior authority of a philosophical superstructure which is built on a universal scepticism about the efficiency of thought and reason. An Absolute which does not reveal itself in the terms of thought is, for him, a mere word. Hence, while former metaphysics, in the words of Prof. W. Wallace, "had dashed itself in vain against the reefs that girdle the island of the supersensible and noümenal, the supposed world of true being," he substituted for "the distant and transcendent Absolute which was the object of older metaphysics an Absolute self-revealing in the terms of thought."[1] This brings out, with an unmistakable precision, the wide gulf which separates Indian absolutism from

[1] *Prolegomena to Hegel's Logic*, second edition, p. 387.

that type of idealistic speculations which became the common property of thinkers from Hegel onward.

THE IDEA

Whatever may be our final attitude to the problems raised above, this should not prejudice our judgment about the facts. Hegel could never sympathise with Shankara when the latter insists on the pure unity of Brahman, for this in the absence of determinations is a simple blank vacuity which can explain neither itself nor its 'other.' It does not matter, he points out, whether their abstract identity be named space, or time, or pure consciousness, ego; in so far as it is an abstract absolute, it lacks the condition of a synthesis, which consists in mediation or a reference to another; "it is quite the same thing as what the Indian names Brahman, when, externally motionless and no less internally emotionless, looking years long only to the tip of his own nose, he says within himself just *om*, *om*, *om*, or perhaps just nothing at all. This dull void consciousness, conceived as consciousness, is Being."[1] But to plant ourself thus fast in the abstract absolute is an impossible feat for thought; thus "Parmenides with his *illusion* and his *opinion* must consent to own an opposite of being and of truth; as, similarly situated, is Spinoza with his attributes, modes, extension, motion, understanding, will, etc. The synthesis involves and shows the untruth of those abstractions; in it they are in unity with their other—not, therefore, as self-subsistent—not as absolute, but directly as relative."[2] Knowledge, for Hegel, cannot find self-fulfilment in this abstract identity of pure being, its ideal cannot be a thing existing "not under relation," for

[1] Dr. J. H. Stirling, *The Secret of Hegel*, p. 233.

[2] *Ibid*, p. 234.

duality is the very essence of intelligence.[1] Its ideal is rather to be found in " the pure transparent identity-in-difference of self-consciousness "; and consequently, the absolute idea is the idea of " a self-consciousness which manifests itself in the difference of self and not-self, that through this difference, and by overcoming it, it may attain the highest unity with itself." Indeed this description of the Absolute has been unanimously accepted by occidental philosophy from the time of Hegel onward, and it has completely replaced the agnostic description of a relationless Absolute. The Absolute, says Bradley, is an individual and a system, and it is one in this sense that its differences co-exist harmoniously within one whole, beyond which there is nothing.[2] " Our Absolute," he points out,

[1] It has been urged that " the self-existent Brahman is independent of time space and cause. . . . In emphasising the independence of causal relations, Brahman is represented to be an absolutely static being free from all the laws of becoming of which the universal rule is causality. This way. . . . . leads to misconceptions. . . . . There is no change in Brahman though all change is based on it. . . . . The comprehension of this profound philosophical synthesis cannot be obtained so long as we remain at the level of intellect. It deals with relations and cannot grasp the relationless absolute. But there is nothing on earth existing in space or time which is not an appearance of the absolute. No knowledge is entirely false, though none is entirely true."—Prof. Radhakrishnan, *Indian Philosophy*, I, p. 175. It is however necessary, in view of what has been said above, to distinguish this interpretation from the Vedantic thought as represented by Shankara who is never tired of insisting on the absolute nothingness of the world of appearance when regarded from the standpoint of esoteric knowledge. Shankara's absolute, it is hardly necessary to repeat, has as little room for space, time and causality as Kant's Thing-in-itself. The Brahman is the ground of the phenomenal world only from the standpoint of those who have not attained right knowledge. On the other hand, it is equally important to remember that Hegel at least could not believe in a " philosophical synthesis " which has to be achieved through something other than the relating intellect. Knowledge for him is a transparent relation. In perfect knowledge, to quote Prof. A. Seth, " the difference of subject and object is, in the current phrase, transcended or overcome. But this does not mean that it disappears, and that the two sides fall together in a blank or pure identity."

[2] *Appearance and Reality*, Part II, Ch. 2.

"is no Thing-in-itself. It is against this empty transcendence and this shallow pantheism, that our pages may be called one sustained polemic. The Absolute is no sundered abstraction, but has a positive character....The Reality itself is nothing at all apart from appearances." The contrast of such an Absolute with the Brahman of Shankara is too clear to be mentioned in detail. The slightest difference is absolutely incompatible with the pure unity of Brahman, and the synthesis of subject and object upon which the Vedantic monism is ultimately founded is not simply a transparent unity in the Hegelian sense, and so not within the capacity of intelligence. It it rather to be realised through an extraordinary type of vision.[1] To lose sight of this contrast is to court misunderstanding, and confusion. We must admit that the tendency of Shankara's philosophy is mystical, if we agree with Prof. A. Seth Pringle-Pattison,[2] in describing it as the tendency "to exalt the divine above all predicates, making it literally the unnameable, the ineffable, the unknowable"; and however indistinguishable it might be from nothing, it is yet the highest or rather the only Reality for the intuitionist. To put this contrast briefly, the Absolute of European philosophy transcends the finite in the sense of being more of the finite. It is simply the finite at its best. The Vedantic Absolute, on the contrary, is transcendent of the finite in the sense that it completely annuls the finite. According to the latter, finite self is an appearance in the sense of being a mere illusion; while for the former it is an appearance in the sense that it points to a fuller reality.[3]

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[1] Prof. Max Muller then is perfectly right when he says that "this constitutes the unique character of the Vedanta. . . . If we have once grasped that synthesis, we know the Vedanta."—*The Six Systems*, p. 170.

[2] *The Idea of God*, p. 220.

[3] Cf. "The common appearances of our lives—of material things, of conduct, and of institutions all carry us a certain way and

Criticism of some attempts at reconciliation.

The relation between Hegel and Shankara in respect of their philosophical views, it has been our endeavour to make clear, is one of unreconcilable opposition. This, we have made an attempt to show in connexion with their philosophical methods as well as the results which follow from them. In fact, their conceptions of the Absolute could not have any essential points of contact in view of the divergence of their philosophic methods. A philosophy that begins with a damaging criticism of conceptual thought is not likely to have any substantial agreement with another which is inspired by a staunch faith in the potency of reason and the universal validity of the principles of thought. The historic importance of Indian Absolutism therefore consists in its being one of the types of anti-intellectual retorts which, like the Bergsonian retort of our time, have their moorings in a deep misology or the distrust of the power of conceptual knowledge to reveal the innermost essence of Reality. Hence Shankara invokes the aid of an immediate experience for knowledge of the Real. We may put these contentions in a clearer light by noticing an interesting, though to our mind misleading, tendency to mitigate the antithesis between intuition and reason either by looking upon intuition as the crown of reason, or by considering reason as the truth of understanding. The former line of reconciliation is suggested by the Indian view of the three stages of *shravan*, *manan* and *nididhyasan* in the complete realization of Truth, and this may be made

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to pronounce them illusory would be a foolish exaggeration."—Dr. Bosanquet, *The Principle of Individuality and Value*, p. 226. The doctrine of Maya, he remarks further on, arises out of confusion on this head; because our facts break down at a certain point, it is forthwith concluded that the world of appearance is a mere illusion. Similarly, with regard to Nirvana and absorption in God he observes that it "however positively construed remains a very different thing from our Absolute with its appearances."—*The Value and Destiny of the Individual*, p. 270.

the basis of insinuating the epistemological inferiority of a system of philosophy which is limited to only one of these three indispensable stages of knowledge. On the other hand, the Hegelian distinction between the standpoint of reason and that of understanding, is sometimes made the occasion for the distant suggestion that Hegel, by recognising the stage of reason beyond that of understanding recognised the partial truth implicit in the Pure Being of intuition. Thus it has been urged,[1] that "the East is apt to believe that only identity is real, and that differences are illusory—which is in fact explicitly stated in the doctrine that only the one is and that the world of difference and multiplicity is Maya, illusion. Its formula is A is A." But this formula, it is pointed out, is "the work of understanding." The Hegelian principle of reason, on the other hand, is the principle of the identity of opposites which "does not oppose, but includes, the principles of the understanding. It only opposes the one-sidedness of understanding." In face of such a disparaging criticism which is in fact suggested by Hegel's treatment of the category of being, the first impulse of those who think that the only way of justifying the study and estimating the value, of Indian philosophy is to extract out of it the quintessence of European thought will be to repudiate this identification of the abstract identity with the Vedantic Absolute and declare that "the Vedantic Absolute is not the abstraction of an *être suprême* which deletes all differences but is a spirit that transcends and at the same time embraces all living beings." "The Maya theory simply says that we are under an illusion if we think that the world of individuals, the pluralistic universe of the intellect, is the absolute reality."[2] This declaration, however, as we have indicat-

[1] Mr. W. T. Stace, *The Philosophy of Hegel*, p. 103.
[2] Prof. Radhakrishnan, *Contemporary Philosophy*, p. 445.

ed above, can hardly be an unprejudiced account of the Vedantic Absolutism. It not only runs counter to what is explicitly taught by Shankara about the Absolute being entirely free from all the conceivable types of difference, but is further irreconcilable with his conception of salvation or emancipation as the immediate consequence of right knowledge realised only in the intuitional experience of identity. It is again a serious misrepresentation of the Maya theory, though it may help us to read the Hegelian theory of transcendence into Vedantism, to interpret Maya as the individual's confusion of the relative with the absolute; for here too we have very explicit statements which unmistakably point to the Absolute unreality of the world of multiplicity. Maya, it must be remembered, is for Shankara the material cause of the phenomenal world which includes everything except the pure *chit*, and not simply a subjective confusion. At the dawn of right knowledge its true character as pure nothing is realised, and with this realisation vanishes the belief of the reality of the phenomenal world. Thus the abstract identity, however defective it may be from the standpoint of conceptual knowledge, is the highest truth from the view-point of intuition. The distinction between these two standpoints is a vital aspect of Shankara's monism. One is *shastra dristi*, which may be translated for our present purpose as the standpoint of intuition, and the other is *yukti dristi* or that of ordinary knowledge. According to the former, Maya never existed in the past, does not exist in the present and will not exist in future; but as judged in the light of the latter knowledge it is both the material cause of the world of multiplicity as well as the cause of our false judgment. It is then entirely unprofitable, and perhaps unnecessary too, to defend the Vedantic Absolutism by putting on it a far-fetched interpretation on the Hegelian line which it can hardly bear: for, if there is any

point which may be fairly taken to be the central core of Shankara's teachings. it is the unity of the Brahman which excludes, and not simply transcends, all differences. Hegel might join hands with Shankara in so far as the latter holds that the Absolute is a unity which is above all differences and in reference to which we must account for all these differences; that it is not a finite thing in the democracy of other finite things or a God which is yet to be; that the distinctions between spirit and matter, subject and object are not absolute. But when Shankara, not satisfied with the ideal of rational or conceptual knowledge, would proceed to point out that this unity is an absolute identity in which all differences disappear, Hegel would surely experience a severe revulsion of spirit as he did in the presence of the Schellingian Identity. The Brahman, he would then point out, is the unity of substance rather than of spirit.

If then it is a mistake to interpret the Vedantic Absolute as the ideal of reason which for Hegel was an identity in difference, no less serious is the error of thinking with the critic that the Vedantic Identity is no better than the abstract identity of understanding. The principle of contradiction which necessarily leads thought to determine or mark off one thing from another, and which accordingly emphasises the self-identity of things in their abstract exclusiveness may stand in need of correction from the standpoint of reason which brings out the impossibility of separating one thing from another so completely as to make their relation disappear. But the Identity which is realized in the intuitional experience is expressly asserted to be unthinkable and consequently the problem of differentiation and relation cannot be fitly raised in this connexion. Two things may differ from each other either in their spatial positions or temporal locations or merely in their contents. But these distinctions cannot be relevant

to what is infinite in the sense of being free from these three types of limitation, or *desh-kal-vastu-parichhedshunya*. In other words, the principle of contradiction which has universal application in the world of plurality or multiplicity is surely a half-truth in so far as it accentuates difference exclusive of relation, and so it was Hegel's great merit to have brought out the secret of the intellectual mechanism which in the very act of differentiating also unifies. But this is entirely irrelevant when we have to refer to what is beyond the mechanism; when the reference is to that which though unthinkable is still realizable in experience. The merit of Hegel, we are then persuaded to believe, so far as the present problem is concerned, is to be judged not with reference to his distinction between understanding and reason, but only in connexion with what he says against the indeterminate or the Thing-in-itself.

A similar confusion appears to lurk in such statements as that "the weakness of the Upanishads lies in this that the synthesis is reached not by explicit reason but by intuition."[1] If reason is thought, then to contrast the intuitional synthesis with the synthesis of reason seems to be as absurd as to contrast, to use Dr. Ward's example, what occurs in a given day with what occurs outside of a given door. That is, we can contrast a thing or event with another only in so far as they belong to a single context of reference; but when the Absolute is supposed to be unthinkable reached not by reason, we cannot possibly institute a comparison between the rational and the intuitional synthesis. It should be however distinctly understood that this does not mean that the intuitional synthesis is above all criticism. Whether it is so or not it is none of our present purpose to discuss. What we

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[1] Prof. Radhakrishnan, *Indian Philosophy*, I, p. 264.

contend for is that an impartial criticism of intuitionalism should not seek a common ground by attributing to it what it expressly denies. So when it is urged by the intuitionist that what is absolutely beyond thought and speech can yet be realized in a living experience, it is not to the purpose to point out that the synthesis is not reached by reason; all that we can do is to consider how far the immediacy of an experience has a higher truth-value than the systematic coherence of thought. This, as we have ventured to suggest on another occasion,[1] is the root distinction between the Hegelian and the Shankarite standpoints.

To turn now to the second type of reconciliation, it has been urged that the thinking consideration of things which is identified with philosophy in the West is only a stage in the complete realization of truth. For the development of *aparoksanubhuti* rational discussions form only a propædeutical measure of self-discipline. Their function is to remove the sense of impossibility about the revealed truths,[2] and thus prepare the way to the actual experience in which alone ‘ reality ’ is apprehended with an immediate or intuitive certainty. It is such expressions as these which apparently lend countenance to the view that intuition is the crown of reason or that rational knowledge seeks self-fulfilment in something beyond reason. On closer inspection however it may be discovered that the Indian position does not admit of such an interpretation; firstly, because it runs counter to the explicitly misological tendency which, as we have noted above, is characteristic of the orthodox systems in general and of

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[1] *The Method of Indian Absolutism*, a paper read at the second session of the Indian Philosophical Congress.

[2] Thus Madhusudan describes ज्ञानं as शास्त्रोक्तानां पदार्थानामौपदेशिकं, and विज्ञानं as तदप्रामाण्यशङ्कानिराकरणफलेन विचारेण तथैव तेषां स्वानुभवेनापरोक्षीकरणम् । *Com. to Gita*, VI. 8, cf. also VII, 2.

Vedantism in particular. Shankara is emphatic on the inefficiency of unaided reasoning.[1] The strength of his conviction in this respect is evident from his reply to a possible objection which,—and he was too acute a thinker not to have seen it,—goes to the very root of the matter. Every serious quest of truth which begins by a repudiation of the claims of thought must sooner or later face the problem if in the very act of proving the incompetence of thinking or reasoning, the validity of proof and consequently that of intellectual processes in general is not presupposed. Thus Bergson anticipating this inevitable objection asks if there is not a vicious circle involved in his attempt to go beyond intelligence.[2] Shankara's reply to this and other allied objections, as is well-known, is that reasoning, based as it is on ordinary perception and inference, is incompetent to grasp the abstruse nature of the ground of the universe; so in such matters its validity has to be ascertained by examining how far its conclusions are supported by the Holy Writ which in turn needs no proof. Whether satisfactory or not, this reply indicates Shankara's implicit faith in the intuitional experiences. Excessive Intellectualism, he says in effect, is not fit for deciphering the mystery of the universe. Discussions and debates however have a function in so far as they are measures of self-discipline indispensable for that profound transformations of our ordinary habits and dispositions leading to the intuitional experiences. This brings us to the second point in our arguments. Shankara's explicit rejection of the Yogic method of knowledge, together with what he says about the need of reasoning is sometimes supposed to

[1] Compare specially, *S. B.* II. 1.6.

[2] *Creative Evolution*, p. 202. Cf. Shankara—नहि प्रतिष्ठितस्तर्क एव नास्तीति शक्यते वक्तुम् । एतदपि हि तर्काणामप्रतिष्ठितत्वं तर्केणैव प्रतिष्ठाप्यते । *S. Bhasya*, II. 1. 11.

be a sufficient proof of his respect for reason; and so it is contended that he at any rate does not found his philosophy on isolated intuitions. The method suggested by him is rather, it is said, that of reasoning which when conducted in the right spirit gives birth to intuitive certainty. It is through *jnanam* and not *yoga* that one is, according to Shankara, to acquire certainty. Now, it is true that the *yoga* and *jnanam* are sometimes described as two different methods of realization.[1] It will however lead to serious confusion of issues if we interpret this as indicating Shankara's rationalistic tendency. He could not surely have failed to notice the absurdity of blowing hot and cold in the same breath. When he accepts *jnanam* as the only method of realization, he does not leave us in doubt as to what he means. *Jnanam* he describes as the ascertainment of what is laid down in the Shastras (शास्त्रोक्तपदार्थानां परिज्ञानं) and it does not become *vijnanam* till the things are actually intuited. So it is apparently unquestionable that the Yogic method and that of Shankara do not differ from each other in so far as an ultra-rational and super-sensuous experience is advocated by both as the highest authority. Shankara however finds in reasoning an indispensable instrument leading to the development of that experience. Reasoning or discussion, if left to itself, cannot produce absolute certainty, for any proposition can be rationally defended provided we have the necessary forensic gift. All it can really achieve is to strengthen our belief in what is laid down in the Shastras by showing that the rational conclusion does not contradict Revelation. In other words, there are, according to Shankara, three stages in the

[1] Cf. *e.g.*, Basistha—द्वौ क्रमौ चित्तनाशस्य योगज्ञानञ्च राघव । योगो वृत्तिनिरोधोहि ज्ञानं सम्यगवेक्षणम् ॥ असाध्यः कस्यचिद्योगः कस्यचित्तत्वनिश्चयः । प्रकारौ द्वौ ततो देवो जगाद परमः शिवः ॥—quoted by Madhusudana, *Com. to Gita*, VI. 29.

development of belief; and reasoning which is necessary at the second stage has the negative function of removing doubt about the truth of the revealed dogma. But belief cannot reach the intensity of absolute conviction till the rational conclusion forms the content of a living experience. Here seeing is believing.

A PROBLEM

The conclusion then seems to be inevitable that the Indian view of the relation between intuition and reason is one of irreconcilable opposition. Intuition might be the crown of reason only if reasoning conducted in an absolutely impartial spirit had for its immediate effect the intuitional conviction. But this it cannot do, for unaided reasoning upon metaphysical subjects is sure to lead to antinomies. Accordingly, Shankara has to warn, as Kant does at a later age, that a truth-seeker should avoid the transcendental illusion of applying the ordinary means of knowledge to things which are strictly metaphysical; and inasmuch as reasoning is one of these ordinary methods of knowledge, it must be always subordinated to intuition. Here arises a problem of vital importance. It has been pointed out by the critics of intuitionalism that in so far as it has to appeal to a subjective conviction as the highest authority, intuitionalism stands self-condemned.[1] For, no theory of knowledge,

[1] Cf., *e.g.*, Prof. W. P. Montague, "The Mediæval monks, the holy men of India, the Mohammedan dervishes, and the Christian Scientists of our own day are but a few of those whose souls have been flooded with an inner light bringing conviction to the mind and peace and courage to the heart. . . . That each mystic should attribute the power of his mystical experience to the peculiar technique by which his state of illumination is attained, or to the truth of his particular creed, is natural enough, but of no logical significance."—*The Ways of Knowing*, p. 59.

it is urged, can have a claim to our assent which fails to distinguish between the psychological and the logical validity of an assertion. This, however, leads us beyond the scope of the present essay which is primarily intended to expose the error of reading Hegelian absolutism into the philosophy of Shankara.

SECTION IV

HISTORY

OUTLINES OF A HISTORY OF AYODHYA FROM THE EARLIEST TIMES TO THE MUHAMMADAN CONQUEST

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PREFACE

Ayodhya is second to none among the holy places of Hindu India yet it is an irony of fate that, beyond brief references to it in the provincial and district gazetteers, it has not attracted the attention of scholars. Mathura (Muttra) boasts of an extensive Memoir from the pen of Mr. F. G. Growse, the translator of the Ramayan of Tulasi Das. Benares has been exceedingly fortunate. In 1868 the Revd. M. A. Sherring published *The Sacred City of the Hindus: An Account of Benares in Ancient and Modern Times.* He was followed by the Revd. Arthur Parker in 1895 with his *Handbook of Benares*, by Mr. F. B. Havel in 1905 with his *Benares, the Sacred City* and shortly after by the Revd. C. P. Cape with his *Benares the Stronghold of Hinduism* and last of all by the Revd. Edwin Greaves with his *Kashi.* Even Allahabad in which the religious element is confined to the Confluence (*Sangam*) and the isolated portion called Daraganj, found, though rather late, in Babu Ramanand Chatterji, sometime Principal of the

Kayastha Pathshala, a scholar to write a book called *Prayag*. There is no apology needed therefore for the compilation of this little book. The credit, however, for its appearance in its present shape and at the present time is due to Mr. R. C. Hobart, the popular Deputy Commissioner of Fyzabad, under whom I had the honour of serving a little before my retirement in 1911. More than two years ago he requested me to write a history of my native town. I was then very busy with my Selections from Hindi Literature for the Calcutta University, since pronounced to be a monumental work, of over two thousand pages Royal 8vo. On the compilation of this book a scheme was drawn up and approved by Mr. (now Sir Richard) Burn, one of the greatest orientalists who ever graced the Indian Civil Service. The period ending with the termination of the Hindu supremacy was completed and approved by him. For various reasons it was considered advisable to end the book there, though Sir Richard was of opinion that it should be brought up to date.

The book has no pretension of being a connected history. All materials available have been collected and arranged under separate heads. I have been by my work and other circumstances kept away from Ayodhya and little local information could be obtained. I did, however, long remain there as a student, as an assistant master and lastly as headmaster of the high school, and a great deal of what is written in these pages was collected long ago. Nevertheless no one is better aware of its shortcomings more than myself, especially as English is not my mother-tongue. I hope the scanty materials collected and noted on here may create an interest in this ancient city and attract the attention of archæologists and historians.

CONTENTS

1. ANTIQUITY OF AYODHYA

Ayodhya, now a small town of 5,000 inhabitants, four miles north-east of Fyzabad, "is undoubtedly a place of immense antiquity."[1] It was the old capital of Uttara Kosala, "that happy kingdom in which all that the Hindu race reveres or desires was realised as it can never be realized again, and the seat of the glorious dynasty which began with the sun and culminated after sixty generations of blameless rulers in the incarnate deity and perfect man, Rama. Whether criticism will finally enrol the hero among the highest creations of pure imagination, or accord him a semi-historical personality and a doubtful date, it is barren to speculate: history is more nearly concerned with the influence which the story of his life still has on the moral and religious beliefs of a great people, and the enthusiasm which makes his birthplace the most highly venerated of the sacred places

[1] Nevill's Fyzabad District Gazetteer, page 172.

to which its pilgrims crowd."[1] As the birthplace of Rama it is considered the first of the seven *tirthas* or holy places of pilgrimage and is piously believed to be the greatest and holiest. "Ayodhya, Mathura, Maya, Kashi, Kanchi (Conjeeveram), Avantika, Dwarawati (Dwarka), these seven confer eternal beatitude."[2] Nor should the occurrence of Ayodhya as the first word in the verse be ascribed to the exigencies of metre. Another well-known Sanskrit verse distinctly says that Ayodhya is the head of the *tirthas*.[3] Several of the six *tirthas* owe their sanctity to their connexion with this capital of Kosala. Mathura long before the birth of Krishna was founded by Satrughna, deputed by Rama to kill Lavana, who harassed the *rishis* practising *tapas* (austerities) on the banks of the Jumna. Maya or Mayapuri is another name for Hardwar, where the holy Ganges brought into the world by Bhagiratha, one of the kings of Ayodhya, descends into the Indian plain. Kashi (Benares) is the *smashanbhumi* (cemetery) of Ayodhya.

Ayodhya even to this day is as sacred to Jains as it is to Hindus. In the chapter on Ayodhya in Jain Literature it will be shown that out of twenty-four tirthankaras or patriarchs, twenty-two were of the Solar (Ikshvaku race), and five including the first were born in Ayodhya itself.

"Of Buddhism, Kosala has without doubt a strong claim to be considered the mother. Kapila and Kusinagara, both in Gorakhpur and both of that country (Kosala), are the Alpha and Omega of Sakyamuni, the founder of that faith. It was

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[1] *Oudh Gazetteer*, Introduction, page xxxi.

[2] अयोध्या मथुरा माया काशी काञ्ची ह्यवन्तिका ।
पुरी द्वारावती चैव सप्तैता मोक्षदायिकाः ॥

[3] विष्णोः पादमवन्तिकां गुणवतीं मध्ये च काञ्ची पुरी-
न्नाभिं द्वारवतीं पठन्ति हृदयं मायापुरीं योगिनः ।
ग्रीवामूलमुदाहरन्ति मथुरां तासाञ्च वाराणसी-
मेतद् ब्रह्मपदं वदन्ति मुनयोऽयोध्यापुरीं मस्तकम् ॥

at Kapila that he was born; it was at Ayodhya that he preached, perhaps composed those doctrines which have conferred upon him a world-wide fame, and it was at Kusinagara that he finally reached that much-desiderated stage of annihillation by sanctification which is known to his followers as 'Nirvana' B. C. 550."[1]

Politically, after the extinction of the Solar race, it was the capital of the mighty Guptas for nearly a century, and even under Muslim rule a part of old Ayodhya with the Muslim name of Fyzabad was the seat of government of the first three Nawab-Wazirs and in the reign of Shuja-ud-daula, its splendour excited the admiration of travellers.[2] It has now lost all political importance and is pre-eminently a city of temples, but it is still the headquarters of the Ramanandi sect of Vaishnavas, a sect whose teachings, reflected in the great vernacular Ramayan of Tulasi Das, composed here in 1574 (1631 V. E.), have given a religion and a code of morals with slight local modifications to the whole of Northern India.

2. ABORIGINES OF AYODHYA

Neither archæology nor tradition throw any light on the races which inhabited Ayodhya before the Solar line was established. According to the Ramayana of Valmiki and the Puranas, Manu was the first king on earth and his descendants established kingdoms in various parts of India, including the Deccan. But when Manu formed a kingdom in Ayodhya for his son Ikshvaku, all his subjects could not have been of his own kith and kin. Oriental scholars give a generic name of Dravidian to the original inhabitants of the country, which, according to Dr. Vincent Smith, is one of the most misleading terms ever introduced.[3] That a pastoral tribe inhabited the country, though but sparsely, there

[1] *Oudh Gazetteer*, page 4.
[2] *Oudh Gazetteer*, page 460.
[3] *Early History of India*, page 413.

is not the least doubt. We hear of conflicts between the Suras (gods) and Asuras (demons) in the Vedas and the Puranas. Aryans, however, were never a bloodthirsty people, nor did they carry diseases in their train which were fatal to the conquered and from which they were practically immune. The aborigines, though thrust into the background, were allowed to live a peaceful life. The Suras, who were probably the Aryan inhabitants of the Himalayas, had occasionally to fight the Asuras. They sometimes found the Asuras more than a match for them and appealed to mortal kings such as Dasaratha and Dushyanta to help them but we never hear of any annihilation of the Asuras. We therefore endorse the following remarks in the *Chronicles of Oonao*:—"When the Aryan race invaded the Gangetic valley and the Soorajbunses settled in Ayodhya, the natural course for the aborigines would be to fly to the hills and find refuge in their impenetrable fortresses girded with the deadly Tarai. To the borders of that Tarai, the invaders would pursue them, and garrisons stationed there to check their encroachments would naturally grow into towns.[1] It has before been remarked that the mystic legends leave no impression of a large subject race existing in Oudh but rather of a vast solitude inhabited by a scanty race employed in pasturing cattle. The scene before us at the fall of the historic curtain is an inhabited forest country and a large colony of Soorajbunses occupying Ayodhya as their capital. When the curtain rises again we find Ayodhya destroyed, the Soorajbunses utterly vanished and a great extent of country ruled over by aborigines called Cheroos in the far east, Bhars in the centre, and Rajapasis in the west. The great revolution seems to be satisfactorily explained by the conjecture that Bhars, Cheroos,[2] etc., were the aborigines whom the Aryans had

[1] Probably Bahraich (Bhar-aich) is one of such towns.

[2] To these I would add *Tharus* of Bahraich.

driven to the hills and who swarming down from thence not long after the beginning of our era overwhelmed the Aryan civilisation not only in Saketan[1] and other northern towns but in Ayodhya itself, drove the Soorajbunses under Kanaksen to emigrate to distant Gujerat and spread over the plains between the Himalayas and that spur of the Vindhya range which passes through the south of Mirzapore."[2]

This is the only explanation that can be given of the fact that most of the Rajput estates in Oudh originally belonged to Bhars, from whom they were ousted by Kshatriyas by methods sometimes not strictly chivalrous. Historians have also gone to the length of saying that many of the so-called Rajput clans in Oudh were originally Bhars.

3. AYODHYA IN THE VEDAS

Neither Koshala nor its capital Ayodhya is expressly mentioned in the Vedas.[3] The river Sarayu, however, is invoked in Rig. X. 64. 9 jointly with Sindhu, and Saraswati 'to animate the worshipper promising water rich in balm'[4] showing that as a sacred river it had already attained in that early period of our country's history a sanctity second only

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[1] The writer mistakes Saketan for Sravasti.

[2] *Chronicles of Oonao*, page 27.

[3] No satisfactory explanation is forthcoming of this omission. Mr. Pargiter is of opinion 'that the really famous kings, confident in themselves and their big battalions cared little about the divine assistance which the rishis professed to bestow.' 'The accounts as they stand now generally extol such great rulers as munificent sacrificers, yet the rishis have preserved no hymns composed in their honour.' In the case of kings of Koshala it cannot be said that no rishis capable of song existed during the reign of all these monarchs because the great rishi Vasishtha to whom and to whose pupils quite a large number of hymns are attributed was the court priest of Ayodhya.

[4] Griffith's Rig Veda, Vol. II, page 473.

to Saraswati, though its mention along with the two rivers of the west has led some scholars to surmise that there was also a river of that name in the Punjab. The ruling dynasty, however, fared a little better. In Rig. X. 60. 4 ascribed to King Asamati and addressed to Indra, Ikshvaku, the founder of the Solar line of kings or the tribe of which he was the progenitor, is described as flourishing in the service of Indra', 'rich and dazzling as the Five Tribes that are in heaven,[1] Twentieth in descent from him, Mandhatri, son of Yuvanashva, the second king of that name in the table printed at pages 455—457 was not only a great king but also the rishi (seer) of Rig. VIII. 39. 8. He is the first in sacrifice and the best slayer of Dasyus and Agni is sought for him.[2] In the next hymn, Mandhatri is mentioned as a singer of the same rank as the Angirasas anticipating Rig. X. 134[3] which is attributed to Mandhatri, the express mention of the name of whose father Yuvanashva placing it beyond the shadow of a doubt that the rishi of the hymn was a sovereign of the Solar race. A careful study of this hymn shows the royal character of the singer who prays not only for the destruction of his enemies, the wicked, but asserts that he himself is free from the vices which lead sovereigns to deviate from the path of duty.

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[1] Griffith's Rig Veda, Vol. II, page 464.

[2] Griffith's Rig Veda, Vol. II, page 181.

[3] Never, O Gods, do we offend, nor are we ever obstinate: we walk as holy texts command.

Closely we clasp and cling to you, cling to your sides, beneath your arms.

(Griffith's Rig Veda, Book III, page 580.)

The rishi of this hymn is Māndhatri (मान्धातृ) whereas the king mentioned in the first two is Mandhatri (मन्धातृ). Nobody, however, has ever doubted that the two names were not identical.

4. AYODHYA IN THE PURANAS

A. The Surya Vansa

Ayodhya is pre-eminently the capital of the Solar line of kings. 'The most salient feature that appears on a comparison of the genealogies is the great length of the Solar dynasty of Ayodhya.'[1] From the table given at pages 455—457 it will appear that it contains 123 names, 93 of which ruled before the Great War and 30 afterwards. Even when the whole of Northern India was overrun by hordes of Sakas, Pahlavas, Kambojas, etc., and every kingdom in the north-west and the Madhyadesa had fallen, the Koshala line went down for a time only but was re-established. 'Other dynasties were not so great and important *continuously* as the Solar monarchy and their lists are not handed down with the same veneration and fullness.'[2] Mr. Pargiter says that Koshala from its eastward position escaped various calamities that befell the more westerly kingdoms.[3] I am, however, inclined to think that it was a succession of powerful sovereigns who wielded the sceptre of Koshala for several centuries and kept foreign invaders at a respectful distance, that gave to the seat of their government the cognomen of Ayodhya, the Invincible, and not its eastern or any strategic position, and it was only after the devastating Great War which "constituted a notable *terminus ad quem*, as if a period of considerable prosperity, knowledge, and refinement was succeeded by one of disorganization and darkness,"[4] that the Solar line in common with the whole of India began to show signs of weakness till its extinction after the Great Revolution in the reign of Mahapadma Nanda or earlier, after which Koshala seems to have been included in the Sishunaga and the Mauryan Empires.

[1] J.R.A.S., 1910, page 9.
[2] J.R.A.S., 1910, page 11.
[3] J.R.A.S., 1910, page 10.
[4] J.R.A.S., 1910, page 54.

Even in the Mahabharata the Solar line played a small part and seems to have suffered an eclipse during this period, probably caused by Jarasandha.[1]

This dynasty commenced according to Bentley, who based his calculations on the data in the *Grahamanjari*, in the year 2204 B.C.[2] Manu was the common ancestor of the Solar and Lunar lines,-of the former through his son Ikshvaku and of the latter through his daughter Ila. Manu founded the city of Ayodhya and having defined the boundaries of the kingdom of Koshala gave it to Ikshvaku. Ikshvaku's supremacy seems to have extended over the greater part of Northern India, for we find that one of his sons, Nimi, established himself in Videha and founded the Kingdom of Mithila and another Dishta (or Nedishta) founded Vishala on the Gandak. Mr. Pargiter assuming the date of the Great War at about 1000 B.C. and disagreeing with Duncker 'who gives 4 calculations for the beginning of the Kali age, that is, approximately for the date of the great battle, *viz.*, 1300, 1175, 1200, and 1418 B.C.' remarks that Ayus, Nahusha, and Yayati, who are alluded to in the Rig Veda, would be placed not later than some twenty-three centuries B.C. In the lists given at page 27 of the J.R.A.S., 1910, to which frequent reference has been made by me, Ayus of the Lunar race in the order of succession corresponds to Sashada, Nahusha to Kakutstha, and Yayati to Anenas. Mr. Pargiter's estimate therefore closely corresponds to Bentley's date. The date of the Mahabharata, however, is still *sub judice.* Rai Bahadur Srish Chandra Basu, Vidyarnava, in his learned article on the '*Date of the Mahabharata War*'[3] has gone through the question carefully and comes to the conclusion that the Great War occurred nineteen centuries before Christ.

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[1] J.R.A.S., 1910, page 323.

[2] *Asiatic Researches,* Vol. VIII.

[3] *Sacred Books of the Hindus*—the *Mastya Puranam,* Appendix II.

I shall now proceed to give a short account of such kings of the Solar dynasty as were of any historical importance.

3. *Shashada (Vikukshi).*—From the Buddhist records it appears that the banished sons of the third Okkaka (Ikshvaku) king (Vikukshi) went away towards the Himalaya mountains, . . . and there they founded the city Kapilavatthu (Kapilavastu), on a site (*vatthu, vastu*) occupied and assigned to them by the Brahman saint Kapila, a previous incarnation of Buddha, whom they found dwelling in a hut of leaves, on the banks of a tank on a slope of the Himalayas in *sakasanda, sakavanasanda,* 'a grove of teak trees.'[1]

4. *Kakutstha.*—Paranjaya was the son of Shashada and grandson of Ikshvaku. In the ever-recurring quarrels between Suras and demons he conquered the demons sitting on the hump (*kakut*) of Indra who had assumed the form of a bull, and was therefore called Kakutstha—one seated on the hump.

5. *Prithu.*—According to the Mahabharata, Prithu was the first man who levelled the earth which is therefore called Prithvi. A slightly different account is given in the *Harivansa* and this story is referred to in the first canto of the *Kumarasambhava.* Here the earth is represented as a cow and milked by the gods to produce brilliant gems and phosphorescent plants. Probably Prithu was the first king to introduce cultivation in India and corresponds to Jamshed of the Persians.

10. *Sravasta* founded the city of Sravasti.[2]

12. *Kuvalayasva* killed a demon named Dhundhu and was therefore named Dhundhumara though he lost a number of his sons in the conflict.

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[1] J.R.A.S., 1906, page 163.

[2] Sravasti is now represented by a mass of ruinsc alled Maheth on the south bank of the Rapti, 12 miles to the west of Balrampur in Gonda district.

20. *Yuvanasva II* married Gauri, daughter of Matinara of the Lunar dynasty (No. 20 of the Paurva line).[1]

21. *Mandhatri.*—He was a mighty monarch and it is said of him that from the rising to the going down of the sun, all that is irradiated by his light is the land of Mandhatri, the son of Yuvanasva.[2]

22. *Purukutsa* conquered the Gandharvas who had oppressed the Nagas. It also appears that his daughter Purukutsā was mother of Gadhi (No. 30 of the Kanyakubja line in Mr. Pargiter's list).[3]

25. *Anaranya.*—This king was killed by Ravana of Lanka in his 'triumphant progress through the nations' or more literally, 'campaign of universal conquest,' and the field of battle is still pointed out on the site of the present town of Raunahi about 14 miles to the west of Ayodhya. It does not appear, that Ayodhya was ever invested by Ravana or his supremacy was established even temporarily here. It may, however, be noted that Rama in conquering Lanka after a few generations only paid off old scores.

30. *Trayyaruna.*—This monarch's reign was marred by an unfortunate incident and the following facts have been sifted by Mr. Pargiter from a mass of myth :

Trayyaruna had an only son named Satyavrata. 'In an outburst of youthful wantonness he interrupted the wedding ceremony of one of the citizens and carried off the bride.' The offence was not very serious but the king misunderstanding its real nature disowned and banished him, his only son. Vasishtha knowing the true facts made no attempt to set the king right but allowed the sentence to stand. Satyavrata quitted the capital Ayodhya and made his dwelling near a hamlet of dog-eaters but resentment rankled unceasingly in his mind against Vasishtha, because

[1] J.R.A.S., 1910, page 26.

[2] Wilson's *Vishnupurana*, Vol. III, page 267.

[3] J.R.A.S., 1910, page 26.

Vasishtha might have taken into consideration that his offence did not deserve the punishment meted out to him and should have interposed. Vasishtha had a reason for behaving as he did and acted deliberately. The king then departed to end his days in the forest—a natural course for he must have been heart-broken. When he had gone, Vasishtha held charge of the capital Ayodhya, the kingdom and the royal seraglio—whence it seems that the king had no other son to succeed him. Vasishtha governed (it is said pointedly) in association with the sacrificing priests and religious teachers. This is noteworthy. Nothing is said about councillors or Kshatriyas. The administration evidently passed into a religious regime.[1]

Then followed a period of drought which lasted 12 years. Vasishtha ruled the kingdom during the whole period.[2]

"At that time Visvamitra had placed his queen and his children in a hermitage in the Koshala country, and had departed to the *Sagaranupa* to perform a long course of austerities, the ordeal by which apparently he attained Brahmanhood. It is said his queen proceeded to sell her second son Galava in order to provide maintenance for the rest during the famine. Her residence there must have been known far and wide. Satyavrata interposed, and rescued and supported the son: his motives were two, a desire to please Visvamitra and compassion for the boy. Visvamitra's favour was obviously worth winning in Satyavrata's desperate plight, for Visvamitra was a man of commanding position and character, both as king of Kanyakubja and as one who aimed at Brahmanhood. Satyavrata assumed the burden of supporting Visvamitra's family, and provided them with food from the spoils of his hunting,

[1] J. R. A. S., 1913, page 695.
[2] J. R. A. S., 1913, page 896.

showing them the highest respect as befitted their rank and his own, for he had become king by right on his father's abdication.[1]

'During the intensity of the famine, Satyavrata killed Vasishtha's cow to obtain food for himself and Visvamitra's family. This aroused Vasishtha's wrath who threatened him with vengeance and stigmatized him as the man of three *sankus* or sins, whence the name Trisanku was given to him.'[2]

At the end of twelve years, Visvamitra returned after completing his austerities and was then a *muni*. In gratitude he offered Satyavrata a boon. Visvamitra inaugurated him in the kingdom and offered sacrifice for him in spite of the gods and Vasishtha. This shows that Vasishtha though virtually king of Ayodhya could command no support either from the army or from the people and as soon as Visvamitra (who combined in his person both famous kingship and Brahmanical eminence) advocated Satyavrata's right, Vasishtha's dominion crumbled to pieces.[3]

Vasishtha thus lost both the kingdom and the position of the king's priest and must have been transported with rage against Visvamitra. The only way of revenge open to him was to deny Visvamitra's Brahmanhood. It is needless to say that Visvamitra triumphed in the long run.

31. *Trisanku.*—The story of Trisanku is described in the Valmiki Ramayana, Book I, cantos 57—60, and may be summarised as follows:—

Trisanku was a good king, but desiring to celebrate a sacrifice by virtue of which he could go up to heaven in his mortal body, he requested his family priest Vasishtha to officiate for him; on being refused he next requested his hundred sons who also rejected his absurd proposal. He,

[1] J. R. A. S., 1913, pages 897-98.
[2] J. R. A. S., 1913, page 900.
[3] J. R. A. S., 1913, page 899.

therefore, called them cowardly and impotent and was in return for these insults cursed by them and became a *chandala*. While he was in this wretched condition, Visvamitra, whose family Trisanku had in times of famine laid under deep obligation, undertook to celebrate the sacrifice and invited all the gods to be present. They, however, declined, whereupon the enraged Visvamitra by his own power lifted up Trisanku to the skies with his cherished mortal body. He began to soar higher and higher till his head struck against the vault of heaven when he was hurled down head foremost by Indra and the other gods. The mighty Visvamitra, however, arrested him in his downward course, saying "stay Trisanku" and the unfortunate monarch remained suspended with his head towards the earth as a constellation in the southern hemisphere.[1] The only reasonable explanation of this fact is that Visvamitra gave him celestial dignity by naming a constellation Trisanku after him. His queen was a princess of the Kekaya race.

32. *Harishchandra.*—Of all the kings of Ayodhya who preceded Sri Ramchandra, Harishchandra is the most famous. The story of his strict adherence to truth even at the sacrifice of all that was dear to him is the subject of several Hindi plays which are deservedly popular throughout the country. The Vedic version on which the Puranic stories are based is, however, different and I must again refer to Mr. Pargiter's learned article in the J.R.A.S., 1917, in which the historical value of the episode is discussed.

"King Harishchandra was childless and made a vow that if Varuna would bestow a son on him he would sacrifice the son to him. Accordingly he obtained a son Rohita, and Varuna demanded the sacrifice as soon as the babe was

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[1] The saliva flowing in torrents from his mouth is said to have produced the river Karmanasa which now forms a part of the boundary between the United Provinces and Bihar.

born . . . . It was certainly an extraordinary vow, to promise to sacrifice his son at birth . . . . but in a religious matter of this kind the king would certainly not have acted without consulting his great family priest Vasishtha. At any rate Vasishtha knew of the vow and allowed it to stand till the son was born. When Rohita was born Varuna demanded the sacrifice, but the king succeeded by repeated excuses in staving off his reiterated demands, till Rohita was invested with the accoutrements of a Kshatriya in his sixteenth year. It is evident that the demand was made by some priest in Varuna's name and it is incredible that the king would have gone on temporising all these years without consulting Vasishtha. The inference then is obvious. Vasishtha either permitted the demand or acquiesced in it: he did nothing to propitiate Varuna or save the king; and thus he virtually supported the demand that Rohita should be sacrificed.''

When Rohita was accoutred as a Kshatriya, the king told him of the vow. Rohita refused compliance and departed to the forest. The king then fell ill. Rohita heard of that and returned at the year's end to see his father but was persuaded to go back to the forest. This was repeated at the end of each year till Rohita departed to the forest for the sixth or seventh year. This advice could not be friendly. To urge on a very young prince, who had been nurtured as an only son amidst the best conditions in Ayodhya, indefinite years of hard wandering, with no suggestion of alleviation ultimately, was little better than mocking at his youthful and natural expectations. This persuader is said to be Indra but he was evidently a minion of Vasishtha who had already governed the kingdom for 12 years during the exile of Trisanku and wanted to be in power again. The result would be the same as if Rohita had been sacrificed or was kept in continuous exile. Vasishtha's position was stronger, for Rohita's predicament was worse than Satyavrata's, because Satyavrata had been only banished, but

Rohita's very life was forfeited under a demand asserted in the name of a god. Rohita went back to the forest for his sixth or seventh year. There he met the rishi Ajigarta with his wife and three sons, all starving, and bought the second son Sunahsepa for a hundred cattle. He returned with him to Ayodhya, and the king proposed and Varuna (that is, his priest) accepted the substitution of Sunahsepa as the victim. Rohita would have been anxious to find some way of deliverance, and it would have been a very natural thought on meeting the wretched Brahman family to buy one of the sons as a victim in his own stead. They in their starving condition might have clutched at relief by accepting his offer. By it one member would die but all the rest would escape, otherwise death faced them all. This time nothing kept Rohita away from his father, though the old reasons for Indra trying to dissuade him still held good. Varuna (that is, his priest) accepted the substitute, because sacrificially a Brahman was better than a Kshatriya Vasishtha's interest in the performance of the vow had ceased . . . . The substitution had completely altered the whole position. A human sacrifice was no longer of any use. Still, manifestly, that could not be openly declared, because to avow that would betray what the real intention had been. The only course now possible was to proceed formally with the sacrifice, and yet devise some plan for announcing that Varuna was satisfied without the immolation, and for releasing Sunahsepa. Further, since the scheming had completely failed it would be natural for Vasishtha to take no prominent part in the proceedings, and prudent for him to propitiate the king, whose interests he had betrayed, covertly if not overtly, all those years. Sunahsepa appealed to his maternal uncle Visvamitra at Pushkara for deliverance and Visvamitra followed him to Ayodhya, for his Brahmanhood was now established. When the ceremonies began no one was willing even to

bind Sunahsepa to the post; manifestly no one wanted this sacrifice, even those who had been demanding the sacrifice of Rohita. Visvamitra after making a formal announcement added 'let the munis and the gods preserve him.' It is manifest then that the sacrifice of Sunahsepa was from the first purely nominal and formal. He was released and Visvamitra adopted him as his son."

33. *Rohita* (*Rohitasva*).—He is said to have founded the town of Rohitapura (Rohitas).

39. *Bahu*.—He was driven from his throne by invaders[1] and died afterwards in the forest. His queen gave birth to Sagara who on attaining manhood fought against and finally subjugated the invaders.

40. *Sagara*.—He also subjugated Yavanas, Sakas, Paradas and Pahlavas. He had two wives, Sumati, daughter of Kasyapa, and Kesini, daughter of Raja of Vidarbha. It is said that when he let loose his horse for the hundredth horse-sacrifice, it was stolen by Indra and taken to a place where Kapila was performing his austerities. The sons of Sagara who were in pursuit of the horses suspected Kapila of the theft and wanted to kill him, but the muni opened his eyes and they were reduced to ashes. Sagara, on learning of the death of his sons, sent his grandson Ansumat, the son of Asamanjas, to effect the animal's recovery. The youth proceeding by the (deep) path which the princes had dug, arrived where Kapila was, and, bowing respectfully, prayed to him, and so propitiated him that the saint said: "Go, (my son), deliver the horse to your grandfather; and demand a boon. Thy grandson shall bring down the river of heaven (on the earth)." Ansumat requested, as a boon, that his uncles who had perished through the sage's displeasure might, although unworthy of it, be raised to heaven, through his favour. "I have told you," replied Kapila,

[1] Haihayas and Talajanghas.

"that your grandson shall bring down upon earth the Ganges (of the gods); and, when her waters shall wash the bones and ashes of thy grandfather's sons, they shall be raised to Swarga."[1] 'Sagara, on recovering the steed, completed his sacrifice, and, in affectionate memory of his sons, denominated Sāgara the chasm which they had dug.' It seems to me that Sagara's sons were the first who reached the Bay of Bengal and discovered the ocean.

44. *Bhagiratha.*—He is said to have brought the river Ganges down to the earth.

50. *Rituparna.*—He was a friend of Nala and skilled in the secrets of the game of dice. He taught the game of dice to Nala which enabled him to win back his kingdom and learnt from him the art of managing horses.

53. *Mitrasaha or Kalmasapada.*—A portion of the story of this king appears in the *Arbuda Mahatmya*, an extract from which is given in my *History of the Sirohi Raj.* Here Vasishtha is again in evidence. Kalmasapada while hunting encountered Shaktri, a son of Vasishtha, in the woods and on his refusing to make way, struck the sage with a whip. Shaktri cursed the king causing him to become a cannibal. As soon as the curse took effect, Mitrasaha ate up Shaktri and his brothers. The *Vishnu-purana* modifies this story and says that by a deception practised on him, human flesh was served to Vasishtha and that when the sage found this out he cursed the king for causing him to become a cannibal. The king knowing that he was innocent wanted to curse him in return but was reminded by his queen that it was ill to utter an imprecation upon a holy teacher, and abandoned his intention. Mitra-saha does not seem to have had much respect for Brahmans,

[1] Wilson's *Vishnupurana*, Vol. III, page 382.

for he is again found killing a holy man engaged in dalliance with his own wife.

55. *Mulaka.*—The *Vishnupurana* says that 'when the warrior tribe was extirpated upon earth, he was surrounded and concealed by a number of females from whence is derived the denomination Nari-kavacha (having woman for armour).'[1] How and by whom the warrior tribe was extirpated it is difficult to say unless it was the sequel to the battle between Arjuna Haihaya and Rama Bhargava who also appears as the opponent of Rama, ninth in the descending line from Mulaka.

59. *Dilipa II*, also called *Khatwānga.*—He was a distinguished votary of the Lord. He defeated the demons in the conflict with gods and as he had only an hour more to live, he came in hot haste to his native town and by contemplating on the Lord attained immortality and union with Him.

61. *Raghu.*—He was a mighty monarch and in his campaign of conquest as described in *Raghuvansa*, Canto IV, he subjugated the Eastern Provinces Suhma, Vanga, Kalinga, Pandya, possibly Kerala, Aparanta, Parsikas, Hunas, Kambojas, Mountaineers of Utsavasanketa, and Pragjotish. The Parsikas are evidently old Persians and it therefore appears that Raghu carried his victorious arms out of India also, as far as Persia.

64. **Shri Rama Chandra.**—He is believed to be the greatest incarnation of the Supreme Being and the Great Example of a Great King. Partly by conquest and partly by inheritance He became master of nearly the whole of India. Before His departure to heaven, He made a

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[1] Wilson's *Vishnupurana*, Vol. III, page 310.
[2] Ibidem, pages 318—320, footnote.

partition of His kingdom among His two sons and six nephews installing them as follows:—

Sons :

1. Kusha in Kushawati on the brow of the Vindhyas, the capital of Dakshina Koshala.

2. Lava in Sravasti in Uttara Koshala.

Nephews :

Angada, son of Lakshmana, in Angadi, possibly a small kingdom at the foot of the Himalayas.

Chitraketu (or Chandraketu), son of Lakshmana, in Chandravaktra, also in the same region.

Taksha, son of Bharata, in Taksha-shila (Taxila) in Gandhara country.

Pushkara, son of Bharata, in Puskharawati, also in Gandhara.

Surasena (called Bahushruti in the *Raghuvansa*), son of Satrughna, in Muttra.

Subahu, son of Satrughna, in Vidisa (Bhilsa).

Ayodhya was deserted by Rama, possibly because he apprehended a dispute between the brothers and cousins.

65. *Kusa*.—With the unanimous consent of his brother and his cousins, Kusa was declared Lord Paramount and coming back to Ayodhya restored it to its pristine glory.

82. *Hiranyanabha*.—He was a pupil of Jaimini, founder of the Yoga system of philosophy and communicated the knowledge of spiritual exercises (Yoga) to Yajnavalkya.[1] As a pupil of Jaimini he was also a teacher of the Sama Veda, his cognomen Kaushalya (कौशल्य) placing it beyond the shadow of a doubt that he was a king of Koshala.[2]

94. *Brihadbala*.—He was killed by Abhimanyu, son of Arjuna, in the Great War. The noticeable point in the

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[1] Wilson's *Vishnupurana*, Vol. III, page 323.

[2] Ibidem.

post-Mahabharata kings of the Solar line is the appearance of the following four names :

23. *Sakya*—also the name of the race to which the Buddha belonged.

24. *Suddhodana*—also the name of the Buddha's father.

25. *Siddhārtha*—also the name of the Buddha himself before he attained Buddhahood.

26. *Rāhula*—also the name of the Buddha's son.

Kapilavastu was certainly in the Koshala country but there is no evidence to show that Sravasti, to which the seat of government appears to have been shifted from Ayodhya at this period, was ever included in the kingdom of Kapilavastu or its kings ever reigned there. The existence of a King Siddhartha at this period is proved by the Jain records according to which Mahavira, the last Tirthankara, was a son of the Ikshvaku king Siddhartha by his queen Triśala. Besides, any inference of this nature is rebutted by the fact that Prasenajit (No. 27) (Pasenadi) who had received his education in the University of Taxila[1] went over to the Buddha and confessed that Bimbisara of Magadha and the Lichhavis were his friends.[2] Further account of Prasenajit is given under head 'Ayodhya in Buddhist Records.'

His son Kshudraka (No. 28) is called Virudhaka in Buddhist books possibly because he was hostile to Buddhists, and is notorious for his merciless massacre of the Sakyas.

The last king Sumitra was according to some scholars apparently killed in the great revolution of Mahapadma Nand in 422 B.C. The inscription referred to in page 458 would, however, show that the Solar line terminated at least fifty years earlier.

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[1] J.A.S.B., 1916, page 17.

[2] J.A.S.B., 1921, page 270.

It may, also, be interesting to note that Professor R. Kimora, the great Japanese scholar who visited India a few years ago, believes that the Japanese are a branch of one or other of the great Indian races.[1] The Mikado is believed to be a descendant of Amma, the first Mikado, who was an incarnation of God. This Amma is probably a corruption of our own divine king-incarnate Rama, for additional evidence is furnished by the fact that, according to the Japanese traditions, the Mikados are born in the line of the Sun-god which is perhaps no other than that they are descendants of the Solar race (Suryavansa) of Kshatriyas to which our Sri Rama Chandra, the divine incarnation, belonged.

At what period of history this emigration took place it is difficult to say. That the Kshatriyas of Ayodhya established a kingdom in Tibet and in Siam has been proved beyond the shadow of a doubt and Professor Panduranga Pissulencar of Goa in his interesting research published in the French journal entitled *Lal Couverte l'Ameriqueparle hommes de Inde* has gone so far as to assert that America was peopled and colonised by the ancient people of India.[2]

The Suryavansa or the Solar Line of the Kings of Ayodhya

(Ancient Indian Genealogies and Chronology by F. E. Pargiter, J.R.A.S., 1910, pages 27 and 29.)

PRE-MAHABHARATA WAR.

1. Manu
2. Ikshvaku
3. Sasāda
4. Kakutstha
5. Anenas
6. Prithu
7. Visvagāsva
8. Ārdra

[1] *Hindusthan Review*, Vol. XIV, page 68.

[2] Ibidem, page 66.

9. Yuvanasva I
10. Sravasta
11. Brhadasva
12. Kuvalasva
13. Dridhasva
14. Pramoda
15. Haryasva I
16. Nikumbha
17. Samhatasva
18. Krisasva
19. Prasenajit
20. Yuvanasva II
21. Mandhatri
22. Purukutsa
23. Trasadasyu
24. Sambhuta
25. Anaranya
26. Prisadasva
27. Haryasva II
28. Vasumanas
29. Tridhanvan
30. Trayyaruna
31. Trisanku
32. Harishchandra
33. Rohita
34. Harita
35. Chanchu (Champa according to *Bhāgavata Purana*)
36. Vijaya
37. Ruruka
38. Vrika
39. Bahu
40. Sagara
41. Asamanjas
42. Amsumat
43. Dilipa I
44. Bhagiratha
45. Sruta
46. Nabhaga
47. Ambarisa
48. Sindhudvipa
49. Ayutayus
50. Rituparna
51. Sarvakama
52. Sudasa
53. Kalmasapada
54. Asmaka
55. Mulaka
56. Sataratha
57. Vriddhasarman
58. Visvasaha I
59. Dilipa II
60. Dirghabahu
61. Raghu
62. Aja
63. Dasaratha
64. Rama
65. Kusa
66. Atithi
67. Nisadha
68. Nala
69. Nabhas
70. Pundarika
71. Kshemadhanvan
72. Devanika
73. Ahinagu
74. Paripatra
75. Dala
76. Sala

77. Uktha
78. Vajranabha
79. Sankhana
80. Vyusitasva
81. Visvasaha II
82. Hiranyanabha
83. Pusya
84. Dhruvasandhi
85. Sudarshana
86. Agnivarna
87. Sighra
88. Maru
89. Prasusruta
90. Susandhi
91. Amarsa
92. Mahasvat
93. Visrutavat
94. Brihadbala

Post-Mahabharata.

(*Sacred Books of the Hindus*, *Matsya Purana.*)

1. Brihatksaya
2. Uruksaya
3. Vatsadroha (or Vatsavyuha)
4. Prativyoma
5. Divakara
6. Sahadeva
7. Dhruvasva (or Brihadsava)
8. Bhanuratha
9. Pratitasva or Pratipasva
10. Supratipa
11. Marudeva or Sahadeva
12. Sunaksatra
13. Kinnarasva or Puskara
14. Antariksa
15. Susena (Suparna or Suvarna or Sutapas)
16. Sumitra (or Amitrajit)
17. Brihadraja (Bhraja, or Bharadvaja)
18. Dharma (or Viryavan)
19. Kritanjaya
*20. Vrata
21. Rananjaya
22. Sanjaya
23. Sakya
24. Suddhodana (Kruddhodana)
25. Siddhārtha
26. Rāhula (or Ratula, Bahula, Langala, Pushkala)
27. Prasenajit (or Senajit)
28. Kshudraka
29. Kulaka (Kshulika, Kundaka, Kudava, Ranaka)
30. Suratha
31. Sumitra

* This name does not occur in the *Matsya Purana* but appears in the *Vayu Purana.*

B. The Sisunagas, Nandas, Mauryas and Sungas

Sisunagas.—Evidence of Sisunaga rule in Ayodhya is extremely meagre, but it cannot be ignored. The following remarks under head *Mani Parbat* appear in the *Oudh Gazetteer*, page 10:—

'*Raja Nanda Bardhan of Magadha.*—I have repeatedly been assured by Maharaja Man Singh that within the present century an inscription was discovered buried in this mound, which ascribed its construction to Raja Nanda Bardhan of the Magadha dynasty, who once held sway here. The Maharaja further stated that the inscription was taken to Lucknow in Nasir-ud-din Haidar's time, and there was a copy of it at Shahganj, but all my attempts to trace either the original or copy have failed.'

Again in the footnote:—

'This information has since been corroborated by the learned Pandit Umadatt of Ayodhya, who informs me that he made a translation of the inscription between thirty and forty years ago. He, too, has lost his copy and cannot now describe the contents.'

There is no reason to disbelieve any of these personages. Pandit Umadatt (Pandit Umapati Tripathi) was one of the holiest men in Ayodhya in my childhood and neither the Maharaja nor the Pandit could possibly have any interest in giving false information, especially when the construction of the Parbat by a sovereign 'who is accredited with the suppression of Brahmanism in Ayodhya, and with the establishment of the non-caste system adopted by society generally, when the population at large were denominated Bhars,' would strike at the root of the Brahmanical tradition about it.

Now there were two Nanda Bardhans (Nandi Vardhans) *viz.*, No. 5 of the Pradyotas (d. 782 B.C.) and No. 9 of the Sisunagas (d. 465 B.C.). We have various reasons for choosing the latter. As his great grandfather Ajatasatru was converted to Buddhism by the Master himself, his successors may be presumed to have also been Buddhists and one of them showed his zeal not only by suppressing Brahmanism but by building a large *stupa* which stands to this day.

Nandas.—Nandivardhana's successor Mahanandin was killed by Mahapadma Nanda and the Nanda line commenced in 422 B.C. The kingdom of Koshala naturally passed on to the successors. Mahapadma Nanda reigned for 88 years. When the father's reign is of unusual length, the sons cannot possibly rule long. His eight sons sat on the throne for 12 years only, when the last of them was killed by Chanakya who installed Chandragupta Maurya on the throne of Magadha in 322 B.C.

Mauryas.—The first three Mauryas practically governed the whole of India, including the present Afghanistan.

Salisuka was the fourth in succession from Asoka and according to Garga's *Brihat Sanhita*, 'in his reign, the viciously valiant Greeks reduced Saketa, Panchala and Mathura and reached Patna.'

This invasion, however, seems to have been only a predatory excursion and passed like a whirlwind over the country.

The Maurya empire lasted for 137 years from 322 B.C. to 185 B.C. and was terminated by Pushyamitra, a general in the army who killed his master.

Sungas.—Pushyamitra was a Sunga and founded the Sunga empire. His reign lasted for thirty-six years from 185 B.C. to 149 B.C. He was a staunch advocate and supporter of Brahmanism and consequently a great persecutor of Buddhists. It is said that he burned monasteries and slew monks from Magadha to Jalandhar in the Punjab. He performed several horse-sacrifices, one of which is mentioned in

the well-known Sanskrit drama *Malavikagnimitra*, the hero of which is his son Agnimitra who was governor of Vidisha in the lifetime of his father. The great grammarian Patanjali seems to have presided at one of these sacrifices.[1]

Though governed from Pataliputra, Ayodhya seems to have been prosperous enough to have tempted Menander, who invested it 154 B.C. as recorded by Patanjali[2], though the invasion was repelled after a severe struggle and the Greek king was obliged to retire to his own country.

Pushyamitra was succeeded by Agnimitra who reigned for eight years. He was followed by eight other kings who ruled in aggregate for 58 years.

An inscription lately unearthed in Ayodhya shows that a king of Koshala who was sixth (in descent ?) from the General Pushyamitra built a house in the memory of his father Phalgudeva. The name of this king begins with Dhana which may be Dhana Mitra but there is none of that name in the Puranic list of the ten Sunga kings of Pataliputra. The word Koshaladhipa shows that he was the ruler of Koshala only with his headquarters not at Sravasti but at Ayodhya.

There is absolutely no reason to doubt the genuineness of this inscription. It is in the form of Brahmi inscript current in the second century of the Christian era and the language is Sanskrit.

Sungas were succeeded by Kanvas but Ayodhya seems to have dwindled into insignificance. It is true that several coins presumably of the first century of the Christian era have been found in Ayodhya. " The coins are divided into two classes. One class includes square coins which were obviously cast, and the devices usually include the Bodhi tree and the combined Buddhist symbols of the Tri-ratna and Dharma-chakra. The kings whose coins bear th ese

[1] पुष्यमित्रं याजयाम :

[2] अरुणाद् यवन : साकेतम्

types are Mula Deva, Vaya Deva, Vishakha Deva, Dhana Deva, and Shiva Datta. The other series includes a set of round coins struck from dies usually bearing the device of a bull facing an upright standard or sacrificial post on one side and a cook and toddy palm on the other. The kings known are Satya Mitra, Sarya Mitra, Sangha Mitra, Vijaya Mitra and Kumuda Sena. The two last kings replace the cook and palm tree by the Buddhist symbol of the earlier series, and there is some reason to think that Kumuda Sena came before the others."[1]

In the second century some Kshatriyas of Ayodhya under Kanakasena migrated to Guzerat and laid the foundation of the Vallabhi kingdom whence they spread into Rajputana.

In the third century of the Christian era, nine very powerful and wise kings celebrated as Meghas[2] ruled in Koshala but nothing more is known about them or their successors the Devarakshitas.

5. AYODHYA IN JAIN LITERATURE

Jain Sanskrit literature is loud in the praises of Ayodhya which it also calls Vinita. The description of the city in the *Tilaka Manjari* of Dhanapala edited by Pandits Bhavadatta Shastri and Kashinath Pand urang Parab and published by Tukaram Javaji, Bombay, kindly sent to me by the great Jain scholar Babu Puran Chand Nahar of Calcutta, would vie with Bana in leaving out nothing which constituted a prosperous Hindu city. It was, to quote one of such phrases, a place where Sol for the pleasure of his progeny (kings of the Solar line) had collected the brightness of the universe and where the gardens outshone paradise. According to the *Trishashthi-shalaka-purusha Charita*, Prathama Parva (Canto 2), published by the Adishwar Prasarak

[1] Nevill's *District Gazetteer, Fyzabad*, page 146.

[2] From an inscription lately found it appears that the present district of Allahabad was included in the dominions of these Meghas.

Sabha, Bhawanagar, it was the diadem of the earth and was built by Yaksharaja (Kuvera, god of wealth) under orders of Indra. The city was twelve yojanas in length and nine in breadth and was furnished with an inexhaustible supply of grain, cloth, money and jewels.

The Jains believe in twenty-four Tirthankaras or Patriarchs. Of the various events connected with the lives and careers of these Tirthankaras, the Jains attach great religious importance especially to five things which they designate by the phrase Kalyanakà Bhumi, and they are :—

(i) the last place previous to his being conceived in the womb ;

(ii) the place of his birth;

(iii) the place where he first renounced the world and was initiated into a religious life;

(iv) the place where he first became a *kevalin* or achieved omniscience ;

(v) the place where he realized emancipation.[1]

My friend Mr. Puran Chand Nahar, a great scholar and a prominent member of the Jain community, informs me that Ayodhya is credited with as many as forty-five kalyanakas.

The twenty-four Tirthankaras are as follows :—

1. Adinatha, better known as Rishabha Deva, belonged to the Ikshvaku race and was the son of King Nabhi and Queen Marudevi.

2. Ajitanatha belonged to the same race and was son of King Jitashatru and Queen Bijoya.

3. Sambhavanatha was son of King Jitari and Queen Sena and belonged to the same race.

4. Abhinandana was born of King Sambara and Queen Siddharthā belonging to the Ikshvaku race.

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[1] *Epitome of Jainism* by Nahar and Ghosh, pp. 678-79.

5. Sumatinatha was the son of King Megha by Queen Mangala at Ayodhya belonging to the Ikshvaku race.

6. Padmaprabha was the son of King Sreedhara by Queen Sushima. He belonged to the Ikshvaku race.

7. Suparsvanatha was the son of King Pratistha and his mother was Prithivi and belonged to the Ikshvaku race.

8. Chandraprabha belonged to the Ikshvaku race and was the son of King Mahasena by Lakshmana.

9. Subidhinatha was the son of King Sugriva and Queen Rama belonging to the Ikshvaku race.

10. Shitalanatha belonging to the Ikshvaku race was the son of King Drirharatha and Queen Susnanda.

11. Shreanshanatha also belonged to the Ikshvaku race and his parents were King Vishnu and Queen Vishna.

12. Vasupujya came of the same Ikshvaku race and was son of King Vasupujya by Queen Jaya.

13. Vimalanatha was the son of King Kritavarma by Queen Shyama belonging to the Ikshvaku race.

14. Anantanatha belonged to the Ikshvaku race and was the son of King Sinhasena by Queen Sujasa.

15. Dharmanatha was the son of King Bhanu and Queen Suhrita belonging to the Ikshvaku race.

16. Shantinatha belonged to the Ikshvaku race and was the son of King Visvasena by Queen Achira.

17. Kunthanatha was the son of King Sura by Sree belonging to the Ikshvaku race.

18. Aranatha was born in the city of Hastinapura and his parents were King Sudarshana and Queen Devi belonging to the Ikshvaku race.

19. Mallinatha belonged to the Ikshvaku race and was the daughter (according to Digambaris, who do not admit of *moksha* for the women, she was a son) of King Kumbha by Prabhavati.

20. Muni Subrata belonged to the race known as Hari Vansa and was the son of King Sumitra by Padmavati of the

city of Rajgir where he was initiated and reached *nirvan* on Mount Samet Sikhar.

21. Neminatha belonged to the Ikshvaku race and was the son of King Bijoya and Queen Bipra.

22. Neminatha also known as Arista Nemi belonged to the Harivansa. He was son of Samudra Bijoya by Shiva.

23. Parsvanatha belonged to the Ikshvaku race and was the son of King Asvasena by Bama Devi.

24. Mahavira or Vardhamana, also known as Natputta, the last Tirthankara, belonged to the Ikshvaku race and was the son of King Siddhartha by Queen Trisala.[1]

It will be seen that twenty-two of these claim to be princes of the race of Ikshvaku though none of them appear to be sons of ruling sovereigns. According to the Puranas, Rishabha Deva's father King Nabhi was the descendant of Manu Svayambhuva whereas Ikshvaku was a son of Manu Vaivasvata (Manu, son of the Sol).

Five of these, namely, Rishabha Deva, Ajitanatha, Abhinandana, Sumatinatha, and Anantinatha were born in Ayodhya and temples have been built by pious Jains to mark the sites of their birthplaces.

All my attempts to find out if there ever was a Jain king of Ayodhya, have failed. In fact there is no evidence that a Jain dynasty ever ruled in any part of India, though there are isolated instances of kings like Kumarpal Sulanki of Annhalwara who was converted to the Jain faith by the saint Hema Chandra. The *Oudh Gazetteer* says that the 'trans-Gogra Sribastam' dynasty which ruled in Ayodhya for a considerable period till it was overthrown by the Gaharwars of Kanauj was of the Jain persuasion. The Garhwa inscription of 1199 V. E. records the building of a temple of Navagraha (the nine planets) by Thakkura Ranapala, son of Thakkura Sri Kundapala Srivastavya Kayastha. This shows that

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[1] *Epitome of Jainism* by Nahar and Ghosh, Appendix D.

the Srivastavya Kayasthas in the twelfth century of the Christian era were men of sufficient importance to be addressed as Thakkurs (modern Thakur) and could not have been Jains or Buddhists. The Sribastams (Srivastavyas) of Ayodhya, like the compiler of this history, except for association with other Kayasthas, are total abstainers and take meat very sparingly. This may be some ground for presuming that they were originally Jains.

6. AYODHYA IN BUDDHIST RECORDS

" Closely connected with Ayodhya is the other great name of Oudh, a name greater than that of Rama, if human greatness be measured by the mark which it makes on the world's history. Sakya Buddha was a prince of the house of Kapila (near the modern Gorakhpur) which was an offshoot of the Surajbans line of Kosala. Ayodhya was the scene of his labours and his favourite resting place during the rainy season."

" If a creed may be judged by the highest outcome of its moral teaching, by the most perfect efflorescence of its spirit, it may be fairly doubted if it has yet entered into the heart of men to conceive a loftier height of aspiration than that which breathes in the utterance of a later Buddhist master: ' Never will I seek or receive private individual salvation ; nor enter into final peace alone, but for ever and everywhere will I live and strive for the universal redemption of every creature throughout all worlds. Until all are delivered, never will I leave this world of sin, sorrow and struggle but will remain where I am.' "[1]

Ayodhya is called Sāketa and Vishākhā in Buddhist records. The *Divyavadāna* explains the word Saketa as follows :—

स्वयमागतं स्वयमागतं साकेत साकेतमिति संज्ञा संवृत्ता ।

[1] *Garden of India*, pp. 64-65.

"It came of itself. It came of itself. It is therefore called Sakēta."

Now in Sanskrit kēta (केत)[1] means invitation and as the prefix ā (आ) reverses the meaning, āket (आकेत) would signify 'coming one's self' and with sa (स) would imply "coming of one's own accord with some one."

The origin of the name Vishākhā is thus explained :—

Lady Vishakha is a very important figure in early Buddhist history. She was the daughter of a rich merchant of Rājagriha named Dhananjaya, who had migrated from Rājagriha to Sāketa, and was married to Purnavardhana, son of Mrigara of Sravasti. She was one of the earliest converts to the Buddhist faith and had built for the Master a monastery called the Purvārāma or more fully in Prakrit the Pubbārāma Mrigara-mātuprāsāda, the East monastery, the Palace of Mrigara's mother. She was actually the daughter-in-law of Mrigara but after she had converted him and made him a devout Buddhist she was called his mother. She built another Purvārāma in Ayodhya. It was in honour of this lady that the town was thenceforth called Vishākhā, the Pisokiā of Hioen Thsang. In the Purvārāma of Ayodhya the Buddha is said to have lived for sixteen years.

It was during his stay in Ayodhya that the Buddha threw down a tooth-stick after using it, this took root and grew and flourished and the tree was seen by both Fa Hian and Hioen Thsang. The locality of this tooth-stick tree, in my opinion, disposes of the objection of some scholars in identifying Saketa with Ayodhya.

With respect to Sachi (Saketa) Fa Hian relates that on leaving the town by the southern gate, we find to the east of the road, the place where Buddha bit a branch of the nettle tree and planted it in the ground where it grew to the height

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[1] *Divyavadana* edited by Cowell and Neil, page 1.

of seven feet and never increased or diminished in size. Now this is precisely the legend that is related of Pisokia (Vishakha) by Hioen Thsang who says that to the south of the capital and to the left of the road (that is to the east as stated by Fa Hian) there was among other holy objects an extraordinary tree 6 or 7 feet high which always remained the same neither growing nor decreasing.[1] This is the celebrated tooth-brush tree of Buddha.

Now as we drive along the pucca road from Ayodhya to Fyzabad we find after leaving Hanumangarhi, a sacred tank called the Datun Kund (दतून कुण्ड) to the left of the road. In spite of the popular belief and the Ayodhyā Māhātmya which would make it the reservoir, sitting on the banks of which Lord Rama used to brush his teeth and rinse his mouth, one is tempted to suppose that this tank marks the site either of the old tooth-brush tree of Buddha or of a tank excavated near it, the water of which was piously believed to have been used by Gautama for cleansing his mouth during his stay at Ayodhya. The tree having dried up, the tank still remains to commemorate the sojourn of the Great Master. The southern gate would be somewhere near Hanumangarhi, the *garhi* probably being the southern bastion. From Hanumangarhi to Sarayu fascine is little more than a mile but the river is very changeable in its course and at the time of the pilgrim's visit it may have flowed further north. Within my memory the river has cut away many thousand acres of land of Basti and Gonda districts and many miles of alluvion have been added to Ayodhya.

Hiuen Thsang makes the circuit of the Pisokia capital about 16 li. This could not possibly include within itself the metropolis of a powerful kingdom. I have reason to believe that it was the circuit of Ramkot, the reputed fort of Rama, possibly restored by Guptas. Dr. Fuhrer says that in

[1] *Yuan Chwang's Travels* by Watters, Vol. I, page 399.

Gonda people believe that the tooth-brush tree was *chilbil* which never grows higher than 6 or 7 feet. It may also be *karaunda*, datuns (tooth-sticks) of which are still used in Oudh, especially in Lucknow. It may be interesting to note that there is nothing unusual in the growing of the tooth-brush tree. In Ghatampur town of Cawnpore district, about a mile from the tahsil, there is a large pucca house belonging to a Mahant, in the second storey of which a huge *nim* tree cleft in the middle has grown from a tooth-brush planted on the spot by a *sadhu* 200 years ago. Nothing is further from my intentions than to shake the popular belief by these remarks. The pious votary may still find consolation in the fact that Lord Buddha was as much an incarnation of Vishnu as Lord Rama.

Before giving a description of the Buddhist Ayodhya, it will not be out of place to give an account of the city and its rulers at the time of Buddha's birth, as given in the Buddhist records.

These records do not seem to go beyond the seventh century before Christ. We find there that Ajojjha (Prakrit for Ayodhya) was a town in Koshala on the river Sarayu. So was Sāketa. In mediæval Sanskrit literature the words are synonymous. Kālidāsa in his *Raghuvansa*, Canto XI, calls the city Ayodhyā, and in Canto XVI denominates it Sāketa and there is no reason to believe that the metropolis at the time of Rama's marriage was different from that on his return from exile. "Both cities are mentioned as existing in Buddha's time. They were possibly adjoining like London and Westminster."[1] It may also be conjectured that the part of the town which grew round the scene of Buddha's activities, was called Sāketa, the old site remaining Brahmanic. This may also be said of the street round the monastery built by Vishākhā.

(1) *Buddhist India*, page 39.

The Anjanā Park in which most of the Buddha's Suttas were spoken was in Sāketa.

It has been shown that the seat of government had been shifted to Sravasti. In Buddhist records the sovereigns of Sravasti are called Koshalas. There is nothing unusual in the use of the epithet. We have already seen that Hiranyagarbha of the post-Mahabharata list is styled Kausalya. Their kingdom extended from the mountains in the north to the river Ganges in the south and the Gandak to the east including Benares. In fact the kingdom of Kasi or Benares was the great bone of contention between Koshala and Magadha. Several successful invasions of Kasi by the Koshalans under their kings Vanka, Dabbasena and Kamsa are referred to a date before Buddha's time and the final conquest would seem to be ascribed to Kamsa, as the epithet "conqueror of Benares" is a standing addition to his name.[1] In the seventh century B.C. the Sakyas had also acknowledged the suzerainty of Koshala.

"The kingdom of Kosala before the rise of Buddhism thus included all and more than all of the present United Provinces." The growth of this great kingdom gave occasion and security for peaceful intercourse both of a commercial and of an official kind from one end to the other of its extensive territory. It was precisely these political conditions which favoured also the rapid growth of the institution or custom of the Wanderers[2] of whom we have no evidence prior to the Koshalan power, and who doubtless contributed much to the cultivation of the more intellectual side of the common language which was enabled to grow up under the protective shield of the Kosalan peace.[3]

"This common language was a conversational dialect based probably on the local dialect of Sāvatthi, the capital of

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[1] *Buddhist India*, page 25.

[2] परिव्राजक

[3] *Buddhist India*, page 148.

Kosala, and in general use among the Kosala officials, among merchants, and among the more cultured classes, not only throughout the Kosala dominions, but east and west from Delhi to Patna, and north and south from Sāvatthi to Avanti."[1]

It must be noted, however, that though the metropolis had shifted to Sravasti (Savatthi), Sāketa was still one of the five great cities of Northern India, the other four being Srāvasti, Champa, Koshambi and Kasi.

I have not succeeded in finding a detailed account of Buddha's activities in Ayodhya but it is an established fact that in the Anjana Park as noted above, many of the Buddhist Suttas are said to have been spoken. In the *Abadana* as quoted in the *Buddhist India*[2] Anjana was the maternal grandfather of the Buddha. How he could have a park in Saketa is not easily explained.

We now come to the ancestors of Prasenajit, No. 27 in the post-Mahabharata list. Some doubt has already been expressed regarding the name of the father and grandfather of Prasenajit. In Buddhist books, Prasenajit's father was a Mahakosahla. But Mahakoshala only means great Koshala and we are therefore still left in doubt.[3] Prasenajit was a good king and extended his favour to the followers of all schools of religious thought alike, and this liberality of thought and conduct was strengthened when early in the new movement he proclaimed himself an adherent in a special sense of the Buddha.[4] It may be noted that Asoka in solemnly warning his subjects not to speak evil of their neighbours' faith only carried the Indian toleration a step further. This accounts for the fact that Brahmanism and Buddhism thrived in Ayodhya side by side. Kosala, however, may be justly

[1] Ibidem, page 153.

[2] Ibidem, page 18.

[3] It will be seen further on that in Rockhill's *Life of the Buddha* Prasenajit's father was Aranemi Brahmadatta.

[4] *Buddhist India*, page 148.

proud of having had the first ruler who was initiated by the Master himself. This king was Prasenajit and the following account of this monarch is taken from Rockhill's Life of Buddha:

Prasenajit was a son of King Aranemi Brahmadatta of Sravasti and was born at the same time as Buddha. He was a powerful monarch with a large army. He had two queens, Varshika, a sister of Bimbisara, king of Magadha, noted for her beauty, and Malika, daughter of Sakya Mahanaman of Kapilavastu, renowned for her wonderful touch and for her cleverness. Each of these bore a son to him, Jeta being the son of the former and Virudhaka of the latter.

Sudatta, a wealthy merchant of Sravasti, was the guest of a gentleman in Rajagriha who had invited Buddha to a feast. Here Sudatta heard of the Buddha and went to see him in the grove where he was staying and became one of his followers. Sudatta asked the Master to come over to Sravasti and as there was no *vihara* in Sravasti, promised to make one for him. The site for the *vihara* was selected in a park belonging to Jeta. Jeta demanded an exorbitant price for the plot—as many gold pieces as would cover it. Sudatta agreed but before he had covered the entire plot it occurred to Jeta to make a present of the remainder to the Buddha, free of cost and on this plot Jeta built a vestibule which he gave to the order. The place was called Jetavana by which name it is known to posterity. Prasenajit visited the Buddha while staying here and hearing his sermon of *Kumaradristantasutra* was converted. Shortly after his conversion, Prasenajit sent a message to Suddhodana, king of the Sakyas of Kapilavastu, in which he told him, "Rejoice, O Raja, for thy son has found the drink of the cessation of death (amrita), and he is quenching the thirst of mankind with his nectar." Suddhodana sent repeated invitations to the Buddha and after he had built the Nyagrodhārāma (Banyan grove), the Buddha went to Kapilavastu

and converted to his faith, not only the king but his son and his wife and several other Sakyas.

In the meantime Bimbisāra of Magadha had also been initiated by the Master. His queen Vasavi was of a family from Videha and therefore called Vaidehi, and brought forth a son who was named Ajatasatru. When he grew up he seems to have been persuaded by Devadatta, a rival of the Buddha who had established a schism of his own, to kill his father and become king. His father, however, tried to gratify his son's ambition by giving him extensive territories. Still Ajatasatru was not satisfied. "Then the king relinquished also Rajagriha, only reserving his treasures; but as Devadatta suggested to Ajatasatru that the real sovereign was the one who had the treasures, he prevailed on the king to relinquish these also. Bimbisara complied but at the same time he implored his son to give up his wicked associate Devadatta. Exasperated at this, Ajatasatru had his father cast into prison, there to die of hunger; but queen Vaidehi, the only person admitted to see him, brought him food in a bowl. Ajatasatru heard of this through the jailers and forbade the queen doing so on pain of death. Then Vaidehi had her body anointed with a quantity of nutritious powders, and filled her ankle rings with water; by this means she kept the king alive. This device was also found out, and she was no longer allowed to visit the king. Then the Blessed One walked on the Vulture's Peak, in a place where Bimbisara could see him from his window, and the joy that this gave him kept him alive. Ajatasatru found this out and had the window walled up and the soles of his father's feet scarified."[1]

The parricide then ascended the throne of Magadha but the crime involved him in war with Parsenajit. "Fortune in the contest inclined now to one side, now to the

[1] Rockhill's *Life of Buddha*, page 90.

other ; on one occasion it is said Ajatasatru was carried away as a prisoner in chains to his opponent's capital. Ultimately peace was concluded and a princess of Kosala was given in marriage to the king of Magadha."

In one of the Buddha's visits to Rajagriha, Ajatasatru expressed his remorse for the murder of his father and became a follower of Buddha.

Prasenajit's end was as tragic as that of Bimbisara. He had grown old and Virudhaka seems also to have been getting impatient to become ruler of Koshala. One day while hunting, the prince trespassed in a garden of Sakyas within the suburbs of Kapilavastu. The offended Sakyas tried to kill him but he contrived to escape. Virudhaka wanted to revenge himself on the Sakyas by entering the same garden with a number of soldiers. The Sakyas greatly exasperated, and disregarding the words of their elders, started out to kill Virudhaka. But he, hearing that the Sakyas of Kapilavastu were coming to kill him, said to one of his men, "I am going to hide (with all the troops) ; if the Sakyas ask you anything about me, tell them that I have gone away."

So the Sakyas came to the park, and not seeing Virudhaka, they asked the man, "Where is that son of a slave ?"

"He has run away," he answered.

Then some of them cried, "if we had found him we would have cut off his hands"; others said, "we would have cut off his feet," others would have killed him. "But since he has run away, what can we do ?"

So they decided to have the park purified. "Clean up the park," they said to the workmen ; "and wherever this son of a slave has been, clean it and sprinkle fresh earth (over his footprints). Whatever part of the walls he has had hold of, plaster it over and make it new. Take milk and water and sprinkle it about, and also scented water ; strew about perfumes and flowers of the sweetest kind."

Now Virudhaka's men, who had heard all this, went and told him what the Sakyas had said. Virudhaka was greatly incensed, and exclaimed, " Gentlemen, when my father is dead and I am king, my first act will be to put these Sakyas to death. Promise me that you will give me support in this undertaking."

" He then commenced conspiring against his father and trying to gain over to his interests all the five hundred councillors of Prasenajit, and they all promised him their support with the exception of Dirghacharayan. But even he was subsequently won over, though he kept his intentions secret from his sovereign. One day Prasenajit went to a Sakya town to pay a visit to the Buddha in a chariot driven by Dirghacharayan. On reaching the place, the king out of respect for the Master gave the insignia of royalty to his charioteer and went to the Buddha. The traitor Dirghacharayan at once left the place and on reaching Sravasti handed over the insignia to Virudhaka who thus became king of Koshala. Prasenajit finding that Dirghacharayan had deserted him, proceeded on foot towards Rajagriha. Here he met his queens Mallika and Varshika who had possibly been compelled to leave Sravasti to share the fate of their husband. They informed him that Virudhaka had usurped the throne. Mallika was persuaded to go back and to enjoy the sovereignty with her son, while Prasenajit and Varshika proceeded to Rajagriha and stayed in a park belonging to King Ajatasatru. Varshika was sent to inform Ajatasatru of Prasenajit's arrival at Rajagriha. Ajatasatru was at first alarmed but when he was told that Prasenajit's son has usurped his throne and that he had come to Rajagriha alone with one of his wives, Ajatasatru began to make preparations for his suitable reception. This caused delay and Prasenajit who was sick from inanition went to a turnip field near the park where the gardener gave him a handful of turnips and he ate them, tops and all. This made him thirsty,

so he went to a pool of water and quenched his thirst. Suddenly his hands stiffened, and, seized with cramp in the stomach, he fell by the side of the road and died, suffocated by the dust caused by the wheels of (passing) vehicles."

King Ajatasatru found Prasenajit's dead body lying on the road and accorded to him a funeral worthy of his rank. Queen Varshika seems to have spent the rest of her life in Rajagriha.

It is remarkable that the first two important disciples of Buddha were killed by their own sons. One is tempted to think that they were renegades and avowed enemies of the Brahmans who were in the ascendant in those days and would leave no stone unturned to do away with anything which was calculated to strike at the root of their supremacy.

From the Buddhist records it also appears that a son of Prasenajit went over to Tibet and was its first king. This king ascended the throne in 313 B.C. according to Sanang Setsen and after 416 B.C., the date of his birth, according to Grubnthah sel-kyi-me-long (Sarat Chandra Das, J.B.A.S., Vol. I, page 213). This latter date may be accepted as correct, though there would be still a difference of one hundred and fifty years between the father and the son. Probably the first king of Tibet was only a descendant of Prasenajit. His son Virudhaka who, as noted above, massacred the Sakyas, could not have been a patron of Buddhists, nor is there any evidence to show that any of his successors in the Solar dynasty had much fancy for the new religion.

The Sisunagas, however, as noted in section 5 B, were Buddhists, and Nandi-Vardhana is said to have built the *stupa* now called *Mani Parbat*. Asoka, who is credited with having built 84,000 *stupas* in his empire within the space of 3 years, could not have left Ayodhya alone, and archæological explorations on a grand scale can alone decide whether the mounds such as Shah Juran ka Tila, the Sugriva Parbat and others scattered throughout the town are the

ruins of the *stupas* built by him. There are no stones in Ayodhya and brickwork, unless (like that of Bhitri in Cawnpore) it was hidden, was easily excavated and the bricks used in the erection of new buildings.

The Pushyamitras were enemies of Buddhism, and it is only in the reign of the Guptas that we again hear of the sage Vasubandhu, the great apostle of the Mahayanist creed living in Ayodhya. Vasubandhu was born at Purushapura (Peshawar) of a Brahmin family of Kaushika. He came to Ayodhya and succeeded in converting Vikramaditya. The crown-prince Baladitya, and the queen-mother, both pupils of Vasubandhu, invited him to Ayodhya after the death of Vikramaditya.

Vasubandhu died at Ayodhya at the age of eighty.

Professor Takakusu is confidently of opinion that this Vikramaditya was Skandagupta who ruled about 452—480 A.D. and his successor Baladitya must have begun to reign in 481. Dr. Vincent Smith has gone into the question carefully and comes to the conclusion that Samudragupta received Vasubandhu, the Buddhist author and patriarch, at court, either as a minister or as an intimate counsellor, with the sanction and approval of his father Chandragupta I, and, further that Samudragupta, although officially a Brahmanical Hindu, studied Buddhism in his youth with interest and partiality.[1]

It was in the reign of Chandragupta II that the first Chinese pilgrim Fahian visited Ayodhya which he calls Sachi (Saket). The following account of his journey is taken from *Fahian's Travels* by James Legge, page 55 :—

"Going on from this to the south-east for three *yojanas*, they came to the great kingdom of Shache. As you go out of the city of Shache by the southern gate on the east of the

[1] J. R. A. S., 1905, page 44.

road (is the place) where Buddha after he had chewed his willow branch, stuck it on the ground, when it forthwith grew up seven cubits (at which height it remained neither increasing nor diminishing). The Brahmans with their contrary doctrines became angry and jealous. Sometimes they cut the tree down, sometimes they plucked it up and cast it to a distance but it grew again on the same spot as at first. Here also is the place where the four Buddhas walked and sat and at which a tope was built that is still existing."

The next Chinese pilgrim was Yuan Chwang (also spelt as Hioen Thsang, Huan Chwang, Yuen Chwang, Hiuen Tsiang, Hsuan Chwang, and Hhuen Kwan). He gives a tolerably complete account of the place which I reproduce from *Watters' Travels of Yuan Chwang.*

" The Ayudha country, the Record proceeds to tell us, was above 5,000 *li* in circuit. The country yielded good crops, brought forth fruit and flowers abundantly and had a genial climate. The people had agreeable ways, were fond of good works, and devoted to practical learning. There were above 100 Buddhist monasteries, and more than 3,000 Brethren who were students of both 'vehicles.' There were ten Deva Temples, and the non-Buddhists were few in number.

" Within the captial, the author continues, was the old monastery in which Vasubandhu Pusa in the course of some scores of years composed various *sastras,* Mahayanist and Hinayanist. Beside this monastery were the remains of the Hall in which Vasubandhu had expounded Buddhism to princes and illustrious monks and Brahmins from other countries. Four or five *li* north from the capital and close to the Ganges (Ghogra ?) was a large Buddhist monastery, with an Asoka tope to mark a place at which the Buddha had preached to devas and men for three months on the excellent doctrines of his religion. Four or five *li* west

from this monastery was a Buddha-relic tope, and to the north of the tope were the remains of an old monastery. Here Shih-li-lo-to (restored by Julien as Srilabdha), a sastra-master of the *Sautrantika* school, composed a *Sautrantika vibhasha-sastra*.

" In a mango plantation five or six *li* to the south-west of the city was the old monastery in which Asanga-Pusa had learned and taught. By night the Pusa went up to the Tushita Heaven, and there received from Maitreya the materials of three treatises which he taught by day to his disciples. These treatises, Yuan-Chuang tells us, were the 'Yu-ka-shih-ti-lun,' the 'Chuang-yan-ta-sheng-ching-lun,' and the 'Chung-pien-fen-pielun.' . . .

"Above 100 paces to the north-west of the Mango Grove was a Buddha-relic tope, and besides it were old foundations at the place where Vasubandhu Pusa descended from Tushita Paradise to have an interview with his elder brother Asanga Pusa. Our pilgrim here represents these two brothers as natives of Gandhara, and as having lived in the Millennium succeeding the Buddha's decease (that is, according to the Chinese reckoning, before the third century of our era). Asanga, he tells us, began his Buddhist religious career as a Mahisasika and afterwards became a Mahayanist, and Vasubandhu began his religious career in school of the Sarvastivadins. Yuan-Chuang here tells a curious story about the two brothers and a great scholar who was a friend and disciple of Asanga, by name Fo-te-seng-ha, translated by Shih-tzu-chiao or 'Lion-intelligence,' the Sanskrit original being Buddha-simha. These three brethren made an agreement that when one of them died and went to Heaven he should come back to earth at the first opportunity to enlighten the survivors as to his circumstances. The first to die was the disciple Buddha-simha, but in Heaven he forgot his promise. Then three years afterwards Vasubandhu died and went to Tushita Heaven.

He had been dead six months, and no message had come from him, so the heretics declared that he and Buddhasimha had gone to a bad place. But at length Vasubandhu remembering his agreement, found it in his power to keep it. So in the form of a *Deva-rishi* he descended to earth and visited his brother, telling him how he and Buddhasimha had fared in Maitreya's Paradise."

From this description it appears that when Yuan Chwang visited the place, Buddhism was the prevailing religion. Harsha-vardhana under the influence of the pilgrim had become a Buddhist but the change in Ayodhya could not have been wrought in a day. We are therefore forced to the conclusion that Vasubandhu's influence, as Professor Takakusu remarks, with the last king of the Gupta line, had continued unabated for 150 years.

We next hear of Ayodhya being governed by a Buddhist king at the and of the tenth and the beginning of the eleventh century of the Christian era. The Pala empire included Bengal, Behar, and Oudh (Gaur, Patna and Benares) and the Pala rulers were Buddhists. This king was Mahipal. In the beginning of the eleventh century a great disruption took place, Behar under Mahipal's successors remaining Buddhistic while Oudh under Chandra Deva, a son of Mahipal, became Brahmanic which it is to the present day.

7. AYODHYA UNDER THE GUPTAS

In the early centuries of the Christian era, Ayodhya was in ruins. So complete was the obliteration of the old metropolis that when Vikramaditya made up his mind to restore it, he found the greatest difficulty in tracing its former boundaries. All that was known was that it was situated somewhere on the banks of the Sarayu. According to the tradition, he was encamped near Nirmali Kund when

a black man, to all appearances a king, came on horseback, and as soon as he had bathed in the sacred stream, he at once became much fairer in colour. Vikramaditya was surprised at the change and on enquiry was told by the visitor that he was Tirtharaja (king of *Tirthas* or holy places, Prayag or Allahabad) and that it was one of his annual visits to the place to purify himself by washing off the sins of pilgrims to the Holy Confluence which accumulated and blackened the colour of his body and that the particular place was Nirmali Kund (purifying reservoir).

We have, however, reason to believe that his main clue in tracing the ancient city was the holy river Sarayu and his next was the shrine still known as the Nageshwarnath which is dedicated to Mahadeva and of which he found record in ancient manuscripts. Mention was also made of the different shrines to which pilgrims from afar still flock in thousands.

We have seen in the previous section that in the second and third centuries of the Christian era powerful Meghas and Devarakshitas ruled in Kosala. Possibly their capital was Sravasti. Otherwise there can be no explanation of the desolation of Ayodhya in the fourth century of the Christian era.

This Vikramaditya can be no other than Chandragupta II of the Gupta dynasty "who has a better claim than any other sovereign to be regarded as the original of the mythical king of that name who figures so largely in Indian legend." Chandragupta II was a Saiva but subsequently became a Bhagavata and in the inscriptions, he glories in installing himself Parama Bhagavata. "The Maurya emperors, it is true, had managed to control from the ancient imperial city, a dominion very much larger than that of the Guptas but, even in their time, its remoteness in the extreme east must have caused inconvenience, and a more central position for the court had obvious advantages." Partly from its

central position and partly from the fact that Chandragupta had become a Bhagavata the headquarters of the government had to be shifted to Ayodhya. Tradition, almost universal, attaches Vikramaditya to Ujjain. Though the only evidence of Gupta Rule in Ayodhya is the shape of the columns in the Janmasthan mosque, there is no doubt about this Vikramaditya. The Guptas, however, hailed from Pataliputra. Orientalists forget that the Indian emperors including the Moghuls, Akbar and Jahangir, did not place the same trust in their Viceroys as does the British Government. The western dominions of the Moghul Empire were governed from Lahore where both Akbar and Jahangir resided regularly for some months in the year. From the history of the Pathan kings they learned that viceroys left to themselves became independent sovereigns. Asoka gave full powers to Rajukas, whoever they were, whether Commissioners or Governors, because experience had convinced him that in leaving his subjects to their care "he felt as tranquil as a man does after making over his child to a clever nurse." But this is an exception rather than the rule. Samudragupta had a capital in Jhusi opposite the present city of Allahabad and the stones of the castle built by him were used in the construction of Akbar's fort and some are still lying scattered in the village. The well called Samudrakupa seems to have been inside the fort. Anybody who takes the trouble of walking on foot from Hansakup to Chhatnaga with his eyes open, will find ravines exposing the foundations of masonry walls. The pillar on which Harishena's eulogy has been incised may have been originally erected in Kaushambi but it was in Allahabad when this inscription was engraved. Chandragupta II (Vikramaditya) ascended the throne in *cir.* 375 and conquered Malwa in 395, the chief town of which was Ujjain. Malwa was an exceedingly prosperous province and the country, the people and government excited the

admiration of the Chinese traveller Fahian who came to India in the reign of Chandragupta II. "The annexation of Surashtra and Malwa not only added to the empire, provinces of exceptional wealth and fertility, but opened up to the paramount power, free access to the ports of the western coast; and thus placed Chandragupta II in direct touch with the seaborne commerce with Europe through Egypt, and brought his court and subjects under the influence of the European ideas which travelled with the goods of the Alexandrian merchants."[1]

Have we not, therefore, some ground for presuming that Chandragupta had one of his capitals in Ujjain, and it was from Ujjain that he came to Ayodhya, as described in Canto XVI of the *Raghuvansa* in the case of Kusa crossing the Vindhya mountains and fording the Ganges on the backs of elephants ?[2]

We have now to dispose of another tradition about the duration of Vikramaditya's reign as recorded in the *Oudh Gazetteer*. It says that Raja Vikramaditya ruled in Ayodhya for eight years. Assuming that the capital was shifted to Ayodhya in 400 the eighty years will end in 480, the probable date of the accession of Baladitya when, according to Professor Takakusu, the Gupta empire seems to have come to an end.[3]

But Professor Takakusu's conclusions lead us a little further. Baladitya was a disciple of Vasubandhu and had therefore no attractions for Ayodhya like Chandragupta Vikramaditya. After the dismemberment of the empire partly caused by the invasion of the Huns and partly by the

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[1] *Early History of India.*

[2] *Raghuvansa*, Canto XVI. व्यलङ्घयद् विन्ध्यमुपायनानि पश्यंन्पुलिन्दै रुपपादितानि ।

[3] J.R.A.S., 1905, page 44.

weakness of Kumaragupta's successors, it was considered safer to retire to the old metropolis and Ayodhya fell into the hands of Jogis or Brahmanical fakirs who, acquiring strength, made the place too hot for the weak Buddhist emperor. I cannot refrain from noting another fact which cannot possibly attract the attention of scholars who do not belong to Ayodhya. The mound on which the Janmasthan mosque is built is called the Yajnavedi, the altar. Before the great Govind-dwadasi fair in 1877, when several men were crushed to death inside the mosque, the lane was widened and the sides of the mound were plastered, charred rice was dug out of the mound and grains sold to pilgrims as the rice used in the *Putreshti-yajña* performed by Dasaratha. I am inclined to think that it is the rice of the *yajña* performed at the inauguration ceremony of the new capital by Chandragupta Vikramaditya.

Vikramaditya is credited with having built three hundred and sixty temples in Ayodhya. They have all disappeared except the Janmasthan temple, converted into a mosque by Babar.

The only other reminiscence of Gupta rule in Oudh is the ruined fane in the Devipatan shrine in Gonda district.[1]

A history of Ayodhya is no place for a discussion about the date of Kalidasa, but if he was the court poet of Chandragupta Vikramaditya, he must have come to Ayodhya with his patron and I therefore hazard some guesses about his works which may be taken for what they are worth. A more lengthy note on the subject will be published shortly.

Kalidasa's writings show, as my respected teacher Mahamahopadhyaya Pandit Hara Prasad Shastri, M.A., C.I.E., remarked, that he belonged to a dry, hilly and sandy country,

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[1] *Oudh Gazetteer,* Vol. I, page 368.

and that his birthplace was probably Mandasor and that he first appeared before Vikramaditya at Ujjain. His high genius at once raised him to the dignity of a court poet. *Poets attached to Indian courts are regular courtiers and constant attendants of the sovereign* and even in these days, when the monarch is in his lighter moods, regale him with poetry suitable to the occasion. It was for such occasions that the various chapters of the *Ritusanhara* were composed. It was here that the heir-apparent, who afterwards ascended the throne under the title of Kumara Gupta Mahendraditya, was born and the poem *Kumara Sambhava* (Birth of *Kumara*) in seven cantos was composed to commemorate the occasion. It was when Chandragupta II was staying in Jhusi (old Pratishthanpur) that Kalidasa was reminded of the episode of Pururavas and Urvasi and wrote the *Vikramorvashi*, the scene of which is Pratishthanpur. The word *Vikrama* in the name of the play was simply meant to commemorate the name of the patron.

The Guptas like other Indian kings were very fond of the chase and one of the coins of Chandragupta Vikramaditya shows the king in the act of shooting a tiger. The place where Dushyanta, the hero of the *Sakuntala*, goes on a hunting excursion contains wild boars, bisons and even wild elephants. This can be no other than the north of the present district of Bijnor. It is here that the river Malin rising from the hills of Garhwal after a winding course falls into the Ganges. Hastinapur on the old bed of the Ganges,is fifty miles from here. When leaving for Hastinapur, Dushyanta gives Sakuntal a asignet ring on which his name is engraved. Dushyanta in the Devanagri form current in the Gupta period contains five letters *da sha ya na* and *ta*. The parting lover tells Sakuntala to count the letters each day and tells her that on the fifth day, the last letter in the name, an escort will come to the forest to take her in state to Hastinapur. Kalidasa is never wrong in his geography

and the royal pledge could only be redeemed on the assumption that the hermitage of Kanva was among the hills in Bijnor. It was near this hermitage that Chandragupta II went to hunt, taking his court poet with him. The monarch was not only a good marksman but also a tower of strength. He could go up hill and down dale like a wild elephant. The forest-beaters were instructed to begin their work after midnight. The royal bag was roasted after the hunt of the day was over, and the courtiers shared it with their sovereign at odd times during day. All this may have been pleasant to Chandragupta but the poet had no fancy for it. He did not like to be disturbed in his sleep by rascally forest-beaters. He had no liking for the roast-leg of tasteless venison served to him. He missed the royal dishes which he enjoyed in the palace. He missed his soft downy bed and in the play composed after his return he put his feelings of discontent into the mouth of the Vidushaka.

It is remarkable that though the names of Krishna and Rukmini appear casually in his first play, the *Malavikagnimitra*, the incarnations of Vishnu are conspicuous by their absence in the two dramas. This leads us to infer that these books were written before Chandragupta had become a Bhagavata, and there is no doubt that he became a Bhagavata while he was in Ujjain.

The next precious gem of Sanskrit literature was also composed in Ujjain after the change in the monarch's creed. The journey of the cloud begins with Ramagiri, a place hallowed by the sojourn of the Blessed Couple during their exile. The hill Chitrakuta is referred to as bearing the print of the Lord of Raghu's world-worshipped feet and the emissary cloud is compared to Hanumana and the Yaksha's wife to Sita. Kalidasa loved Ujjain; so did his master, and he could not leave it out of his poem. Though it is not in the path of the cloud marked out for it by the eternal laws of

nature, the messenger is expressly directed to make a diversion, telling him,

> Ah shouldst thou miss
> The glances brisk from lightning-startled eyes
> Of Ujjain's fair thou wouldst have lived in vain.

The court next shifts to Ayodhya and Kalidasa comes to our holy city. Here he commenced that most perfect epic in the whole range of Sanskrit literature, the *Raghuvansa*, in which he has delineated with a true poetic pencil the salient features in the history of "that glorious dynasty which began with the sun and culminated after sixty generations of blameless rulers in the incarnate deity and perfect man Rama." The poem hurries over the successors of Rama down to Agnivarna (No. 86 of the pre-Mahabharata list). He had gone with his master to the Debi Patan at the foot of the Himalayas and describes the mountain scenery in the first and second cantos. He had a first-hand knowledge of the *Digvijaya* (campaign of universal conquest) of Chandragupta II (*not* of Samudragupta) and describes it in Canto 4. He had seen the holy confluence of the Ganges and the Jumna from the fort at Jhusi—a place from which even in these days the finest view of the junction is obtained—and paints it in Canto XIII. He had travelled with his patron from Ujjain to Ayodhya, had seen with his own eyes the desolation of the old city and was present at the inauguration ceremony of the new metropolis which he describes in Canto XVI.

Unfortunately *Raghuvansa* was never finished. The great poet on receiving a call from his Maker selected Sarayu for his final resting-place and consigning his immortal soul to the care of the Lord whom he fervently worshipped, left the works of his art as some of the greatest literary assets of not only the Indian nation but of the entire civilised world.

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[1] A remarkably interesting note on the subject from the pen of Mr. F. G. Petersen has appeared in the October number of J.R.A.S., 1926.

8. AYODHYA UNDER THE JOGIS, BAISAS, SRI-BASTAMS, PARIHARS, PALAS AND GAHARWARS

Jogis.—"According to tradition, Raja Bikramajit ruled over Ayodhya for eighty years and at the end of that time he was outwitted by the Jogi Samudrapal; who having by magic made away with the spirit of the Raja himself, entered into the abandoned body; and he and his dynasty succeeding to the kingdom, they ruled over it for seventeen generations or six hundred and forty-three years which gives an unusual number of years for each reign."[1]

Brahmanism seems never to have lost its influence in Ayodhya even under the Mauryas and after the withdrawal of the Guptas, a priestly government seems to have been established here, the entering of the Jogi into the Raja's body only meaning that he stepped into his shoes. The reign of six hundred and forty-three years from the termination of the Gupta Rule in 480 would bring it to 1123 which is manifestly absurd.

Baisas.—In the reign of Harshavardhana (606—647), Ayodhya was included in the kingdom of Kanauj. It may be interesting to note that coins of Pratapasila and Siladitya who have been identified with Prabhakaravardhana and Harshavardhana by such a high numismatic authority as Mr. (now Sir Richard) Burn, have been found in Bhitaura in Fyzabad district.[2] The description of the city at the time of the Chinese pilgrim's visit has already been given under head Buddhist Ayodhya.

Sribastams.—On the dismemberment of the empire after the death of Harsha in 647 the trans-Ghagra Sribastams (Srivastavyas) seem to have taken possession of the old capital and suburbs. It must be noted that after the depar-

[1] *Oudh Gazetteer*, Vol. I, page 3.

[2] J.R.A.S., 1906, page 845.

ture of Guptas, Ayodhya was governed from a distant seat of government, and sometimes as independent and sometimes as semi-independent rulers, these Sribastams held sway over Ayodhya till the end of the eleventh century of the Christian era.[1]

Parihars.—In the eighth century, Ayodhya became a part of the dominions of the Parihars of Kanauj "who had become masters of the country from Sravasti, 160 miles north-east of Kanauj, to the southern part of Kathiawar and from Kurukshetra on the west to Benares on the east."[2] The most famous king of this line was Bhojadeva also called Adivaraha and Mihira who is distinct from his namesake

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[1] The dispersion of Sribastams seems to have commenced in the twelfth century of the Christian era after the Muhammadan conquest. As remarked by me in the Preface to my English translation of the *Kayastha Ethnology*, the Musalman kings could not dispense with the services of Kayasthas as revenue officers and Mr. Panna Lal, I.C.S., likewise a Sribastam, informs me that a Sribastam of Ayodhya was appointed the qanungo of Asoha pargana, now in Unao district, in the thirteenth century, the functions of the qanungo in those days corresponding to those of the Deputy Commissioner—Settlement Officer under the British Government. We next hear of Sribastams as rajas of Amorha on the other side of the Sarayu. In the fourteenth century, Rai Jagat Sinha, a Sribastam, was subadar of Sultanpur. In 1376, the Dom Raja of Domangarh on the Rapti near Gorakhpur, demanded the hand of a Brahman girl of mauza Kurghand in the Amorha pargana, now in Basti district, and on his request being refused, confined the family to the house. The girl on the pretence of a pilgrimage to Ayodhya went to Rai Jagat Sinha and implored his aid. Jagat Sinha attacked the Dom and having killed him made over the girl to her father who was so overpowered with gratitude that he threw his sacred cord over the Rai's neck saying that he had nothing more valuable to give. Rai Jagat Sinha accepted the gift and his descendants are still called Pandes. Rai Jagat Sinha was made Raja of Amorha by the Delhi emperor and though his descendants were afterwards deprived of half their heritage by Surajbansis, they held Amorha for a considerable period.

Sribastams of Fyzabad and the surrounding districts are still next after Brahmans and Thakurs, important members of the Hindu community and claim such distinguished personages as Maharaja Tikait Rai, minister of Nawab Asafuddaulah, the late General Ramashankar of Balrampur and the late Hon'ble Rai Sriram Bahadur, C.I.E., of Ayodhya itself.

[2] *History of Sirohi Raj*, page 110.

the Pramara, and ruled for fifty years from 840—890. The Parihara Raja Rajpal was reigning in Kanauj when Sultan Mahmud invaded the country. In 1015 the Parihars were overthrown by Gaharwars under Chandradeva. It was during the anarchy after the fall of the Parihar line that "Saiyid Salar Masud Ghazi made his ill-starred advance to Oudh when in the earliest Mohamedan invasion he and his army left their bones to bleach in the wilds of Bahraich."[1] Oudh was then divided into a great many principalities but his chief opponents were, as the writer of the *Oudh Gazetteer* remarks, the Sribastams of Ayodhya though the credit of victory is given to Raja Suhel Deva.

The most famous king of the Gaharwar line was Govindchandra Deva. In 1187 his grandson Jaichand granted the village of Komali to the Brahman Alenga of the Bharadwaj line and the copper-plate grant was found near Fyzabad when Colonel Aulfield was resident of Lucknow. The gods mentioned in the grant are Vishnu and Lakshmi.[2]

Eight years after this, Jaichand was defeatad by Shahabuddin Muhammad Ghori and the Hindu supremacy came to an end.

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[1] *Oudh Gazetteer*, page 3.

[2] J.A.S.B., Vol. X, Part I, 1861.